Life Cycle Assessment – Henry Angus Building

ZHENGXIANG QIU

University of British Columbia

CIVL 498C

November 18, 2013

PROVISIO

a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA

Life Cycle Assessment – Henry Angus Building

ZHENGXIANG QIU

CIVIL 498C

November 18, 2013

Executive Summary

LCA aims to compilation and evaluation of the inputs, outputs and potential impacts of the building system throughout its life cycle, being regarded as a scientific method to analyze the building performance in environment. Some buildings on UBC campus have been involved in the LCA analysis to improve their sustainability. The report would discuss how LCA methodology, database and software work on the object – Henry Angus Building and what the result we get could help us improve the building performance. The initial Henry Angus was built in 1965 at $2,307,309 with an addition in 1976. It was the first “skyscraper” on campus and originally used by Faculty of Commerce and Social Science.

Methods

Based on cradle-to-gate study in the Life Cycle Assessment, firstly we import the building model into “Athena Environmental Impact Estimator” and obtain an overview environmental performance of the building, then adopt Life Cycle Inventor (LCI) analysis to reclassify and quantify the building elements and components in terms of CIQS Level 3format in IE inputs and Impact Estimator respectively. Afterwards, Life Cycle Impact Assessment (LCIA) was used for evaluating each element’s potential environmental impacts. The LCIA profile generates form the analysis presents the elements potential impacts at identified quantity from the material manufacturing, transportation to construction in the light of seven impact category indicators. Last, comparing with UBC benchmark and sensitive analysis, we figure out some material that has more contribution to the Global warming in Level 3 element and inaccuracy in geometry measurement of On- Screen Takeoff and type and property selection in IE Inputs.

Result and interpretation

The identified inaccuracies in geometry and variation between IE Inputs and known measure are likely to cause the distortion about building in LCA for owners, hence we come up with improvements to re-measure or check the inaccurate elements in model to identify their dimension accord to according to reality in practice after evaluating the information form the results of LCI Analysis and LCIA. The outcome would provide the crew with clear and accurate understanding for evaluating the environmental impacts for building whole life cycle as well as t decision maker can regard the result as a guideline for design and manage the building's environmental performance in product and construction stage.

Contents

List of Figures

1. General Information on the Assessment

1.1 Purpose of the assessment

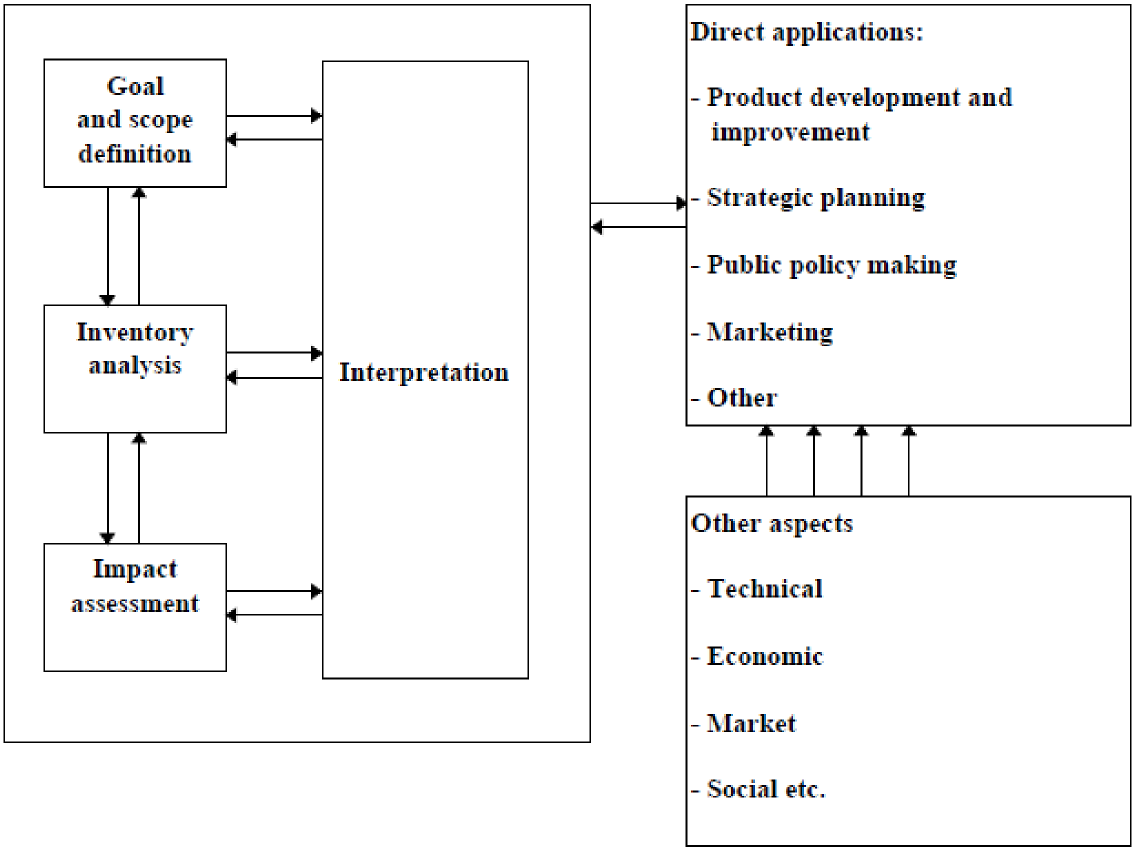


Figure 1- Life Cycle Assessment framework – phase of LCA (ISO, 1977a)

In order to get an explicit understanding on the Life Cycle Assessment, we should figure out what its mechanism is and how the information delivered. The above figure explains the whole framework for Life Cycle Assessment. It is started with the goal of building assessment.

The LCA is considered to be a versatile tool for qualifying the environmental impacts from raw material, production, service. The generic goal of the LCA is to select the best product, process and service with least negative effect on the human health and environment. Specifically, the goal of LCA about exploration on Henry Angus Building aims to these statements primarily:

1.1.1 Intended use of the assessment

- Support product development

  The outcomes of LCA are valuable for users to comprehend the environmental impacts generates from the original building in different life cycle phases, and compare with relative environmental burdens results from improving process or material. The alternative process or material contributes to the product development toward to environmental friendly orientation, reducing the resource requirement and emissions.

- Strategic planning

  The LCA can be applied to make the strategic planning. An increasing number of participators are realizing the importance of the LCA and in pursuit of true sustainability in the built environment. Particularly, the LEED Green Building Rating System is emerged to evaluate the building green performance; When the pursuers make the LEED-oriented building as the strategy, the results of LCA can help pursuers to evaluate their building environmental performance before construction, then LCA scores can be transferred to LEED credits to assess their original design process or materials can meet the requirement of the LEED or not. Thus, they can improve the design or materials in accordance with LEED standard. Also the application of LCA can be considered to be metric to establish the baseline in the life cycle system in terms of manufacture, use and disposal. The baseline information is useful for improving analysis with specific changes in energy consumption and resource use.

- Marketing

Generally, more energy the products consume, the more expensive they are. LCA data helps us analyze and estimate the cost of material by figuring out the amount of energy and resource consumed in production and construction. Depending on the information from LCA material energy consumption, we can select alternative material with lower energy consumption to save cost. Furthermore, the building with LCA can utilize the eco labeling and environmental production declaration caters the customers or stakeholders.

- Policy making

  LCA is used to provide information and direction to decision-maker. Since it contributes to product development, strategic planning, financing, owners can rely on the solid data to make trade-offs of alternative process and materials. The data provides a valid guidance for owner to create a more green building.

1.1.2 Reason for carrying out the study

- Motivations

  With the increasing offending effect from human activities on environment, people are inclined to seek for an alternative approach to evaluate and relieve the environmental impacts. The involvement of many institutions and laws and regulations is to pursue “Green Building” and sustainability. One of the most important characteristics of LCA is the ability to comprehensively examine all the stages that a product goes through. Participants can evaluate the environmental impacts in terms of whole stage of the products used in the construction and identify potential process or environment-sensitive material for improvements from data from the LCA study. LCA has been integrated in to the built environment as tool such as European ENSLIC Building Project guidelines for buildings and implemented that provides practitioners guidance on method to implement

LCI data into planning and design process. The International Organization for Standardization (ISO), in line with others set the ISO 14040 series establishes a uniform framework approach and terminology for LCA. The United States Green Building Council (USGBC) or the Canada Green Building Council (CaGBC) require all building owners, architects, design professionals, engineers and contractors to build in a way that provides for sustainable future based on the LCA study. UBC also establishes Social Ecological Economic Development Studies (SEED) provides the participants with real-world sustainability experience and knowledge and requires some buildings to follow the LCA study to make trade off the environmental impact and benefit with University's net-zero energy strategy. The LCA study of the Henry Angus propagates the sustainable concept to its "neighbor buildings" to help further sustainable development in building construction on UBC campus, contributing to obtain the acceptance in sustainability standards in construction with study maturity growing.

- Objectives

  The data from LCA study can use for comparing the different buildings' performance in different use phase scenarios energy consumption and global warming impacts and identify the significant contributors in two indicators from cradle-to-grave phase. Thus we can control the amount of energy consumption and CO2 emission in accordance with our design strategy by reducing the usage of some specific material or swap them into more green ones.

1.1.3 Intended audience

- Internal audience

  Generally internal audience is related to participants or organization that are prepare to understand or able to get an efficient application in the real practice. As to the project LCA is intended for multiple audiences including the developer, project manager, steel producer. Each of LCA reviewers requires a different level of detail and disclosure to ensure that the accuracy of data without divulging.

- External audience

  The external audience is primarily concerned with public. Some organization such as SEED programs in UBC, Cascadia Green Building Council in Canada and United States Green Building Council that offers the users the with generic guideline to integrate the LCA data into sustainable building analysis, establish world wide database for comparing and sharing data from diverse projects to create uniform benchmark. Another major public audience is government. They have got involved in the match by promulgating some regulations to cater the development of the LCA in the industry.

1.1.4 Intended for comparative assertions

In the model development, the study aims to the exchanging the element material or redefining the geometry based on the drawings, thus the building results include comparison of the performance of original model and improved model in environment. The comparable result is considered to be significant approach for reducing the model environmental impact.

1.2 Identification of Building

The Henry Angus Building is located Northwestern corner of University Boulevard and Main Mall Road as shown the current map of the building in the Fig2. The whole Henry Angus experienced two renovations, original building was built 1965, totally costing $2,307,309, designed by Thompson, Berwick & Pratt in O. SAFIR & CO. LTD. The footprint is outlined in green.

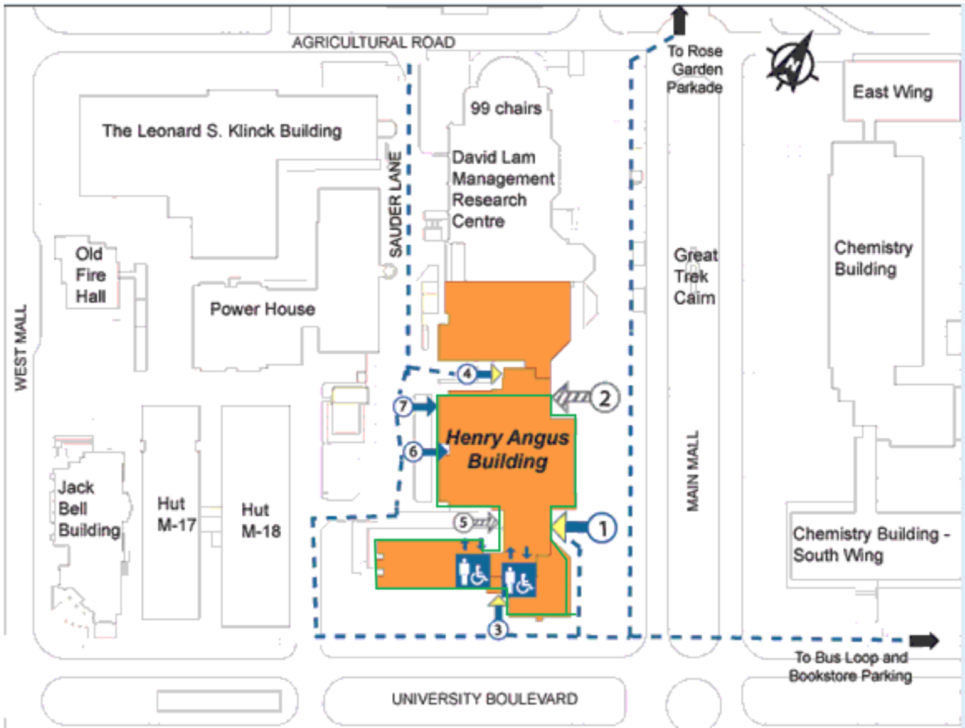


Figure 2 - Location of Henry Angus Building

The preliminary design included two blocks, classroom block and office block, built in reinforced concrete frame and slab. There are two major entrances on the Main Mall Road, one entrance on the University Boulevard and three more on the Sauder Lane. The side of building faces to Sauder Lane approximately remains the original appearance that precast concrete exterior wall with single glazing window in Figure 3.

Figure 3 - Precast exterior wall on west

The 9-floor office block is close to University Boulevard, includes 8-floor office area with basement and penthouse for conference room. As shown in the Figure 4, the primary material of structural section is precast concrete. Basically, the office block can be divided two areas form the No. 3 entrance (see in the Figure 2), the left pare is mainly used for the professors of various department in Commerce Faculty, while the right side is generally for administrative function.

Figure 4 - Office Block Southwest

The classroom block is connected with office block at the junction in No.1 and No.5 entrance. It contains 5 floors with basement and adjacent to David Lam Learning Center on the North side. Apparently, the exterior wall of the classroom is primarily consisting of curtain wall with shading panel.

Figure 5 - Façade of Classroom Block

Figure 6 - Back of Classroom Block

The Henry Angus was the first “Skyscraper” on campus and originally housed the faculty of Commerce. It was named after Henry Forbes Angus, commerce professor and first Dean of Graduate Studies. Since found in 1965, it experienced tow renovation. The first phase worked on 55,000 square feet extension of the classroom block, designed by architect Reno C. Negrin and Associates in 1976. The addition is made up of in-situ concrete and glass on the original exterior wall that of in place concrete and precast concrete frames to the windows because of indication of weathering. Also phase one contains aesthetic improvements with new glazing window on the east side of classroom block and part of south side of office block, as well some electronic and mechanical equipment shown in Figure. 7. In 2003, the addition was renamed as the Sauder School of Business in honor of Chancellor Emereitus of UBC – William Sauder.

The second phase revitalization project of $85M was carried out in 2009 to expend 50,000 square feet to the existing Henry Angus Building and renew space to accommodate the new technology and increasing enrollment students seen in Fig. 8. The lobby of the classroom block is separated into two zones for meeting different requirement in function; one is opening area that provides students with socialization, network, and business community. The other is rest area which offers occupants with amenity food service. Particularly, expanded video conferencing brings global business community into the classroom. Revitalization highlights include:

- The creation of a new facility for the Robert H. Lee Graduate School
- The Bruce R. Birmingham Commerce Undergraduate Centre featuring group and individual study spaces, classrooms, meeting rooms and breakout rooms for small-group work and interviews
- The Middlefield Group Lecture Theatre – a large-size, state-of-the-art lecture theatre with attached conference rooms
- The Jim Pattison Leadership Centre featuring two new lecture theatres, conference rooms and lounge spaces
- The new Hari B. Varshney Business Career Centre – located at the main entrance – emphasizes the crucial link between students and the business community
- Additional classrooms and spaces designed and equipped for distance learning and videoconferencing
- The K.T. Tjia & Anna L.L. Chia Atrium that connects the old building with the new spaces
- A new café and store
- Creation of other open and flexible spaces for students to network, study and congregate in a comfortable environment

Figure 7 - Building before Renovation

Figure 8 - Building after second Renovation

The second refurbishment replaces the façade window of classroom form concrete single window to curtain wall in the figure. 9, the improvement allow more light to shine into the building that saving the energy consumption during the operation. The new four-storey building has classrooms on two levels, a library on one level, two lecture theatres on the top floor and a lecture hall in the basement. The LEED Silver equivalent building is concrete to grade and steel framing above grade with chevron braces and composite beams. In the basement there is a large lecture hall that required that no columns block students' line of site. Glotman•Simpson that was responsible for the structural design utilized large post tensioned transfer beams, spanning 18.8 meters, on the ground floor to allow for no columns in the basement lecture hall space. These beams support the entire building structure above. The roof of Lecture Theater employs long span Glulam beams to accommodate curved sloping roof. The new building had to be seismically separated from the existing adjacent buildings, which were used for gravity support along the east side and parts of the north and south sides. Glotman Simpson provided horizontal slip connections at the building to building joints to allow the new building to move independently. The opening atrium used a mass of wood to take placement of concrete, and the curtain wall of the lecture theater replaces original concrete wall with glazing window as well. The extensive roof glazing introduces cascading lighting through the continuous interior and reflected by the curtain wall of theater to make the lobby get more natural light.

Figure 9 - Interior renewal and expansion

1.3 Other Assessment Information

It has been 48 years since the original building was in construction. Now there are almost 200 staff and 2000 undergraduate students participating in building. It is necessary for us to implement the analysis about the building life span. In the research, we adopted the software Athena Impact Estimator version 4.2.0208 for building LCA analysis. The following table provide a summary of assessment information.

Client for Assessment	Completed as coursework in CIVL 498C technical elective course in Civil Engineering at the University of British Columbia.
Name and qualification of the assessor	Zhengxiang,Qiu & Man-Hin Lo in Civil Engineering Graduation Program
Impact Assessment method	The Athena Impact Estimator version 4.2.0208.
Point Assessment	48 years.
Period of validity	5 years.
Date of Assessment	Completed in December 2013
Verifier	Student work, student not verified.

Figure 10 - Summary of Assessment Information

2. General Information on the Object of Assessment

2.1 Functional Equivalent

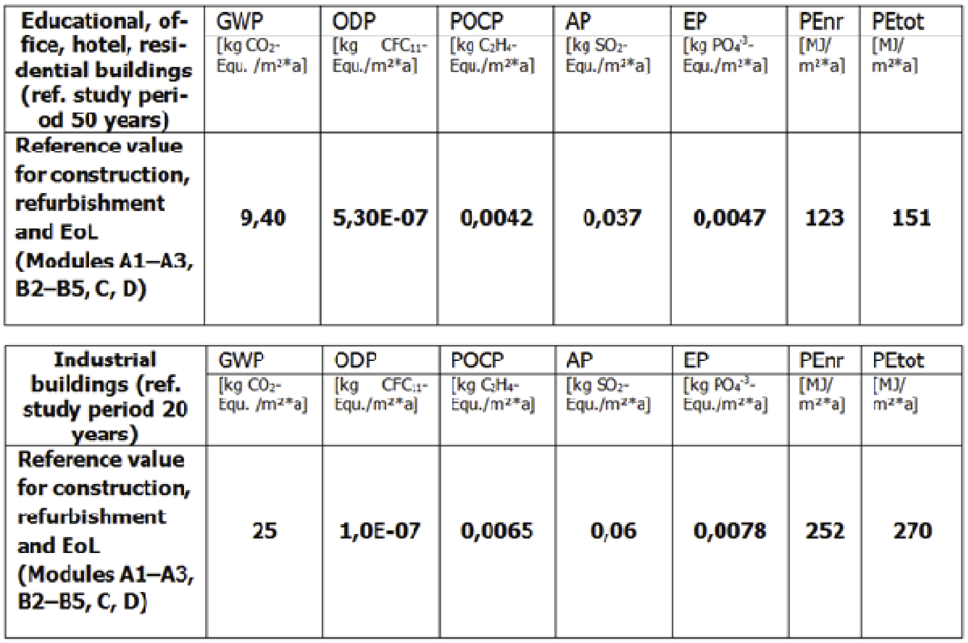
Functional unit is defined as a performance characteristic of product system being studied that will be used as a reference unit to normalize the results of the study. Being a reference, it is necessary to ensure comparability of LCA results, since comparability of LCA results is particular important for assessing different systems to make the comparisons to be evaluated under common metric, moreover, it sets up criteria for the two or more products comparison contributes to improvement, specifically, when participants compare the different products expected achieving the same function. Also functional unit can be regarded as one of guideline of LCA data divide and representation. For example, the environmental impact in LCA data report actually follows the functional unit (e.g. CO2/product). Appropriate defines the functional unit benefits the data disaggregation in LCA based on the specific strategy of the LCA study and provides on overall representation of al product systems include the building analysis scope.

Aspect of Object of Assessment	Description
Building Type	Institutional Building
Technical and functional requirements	Classroom, office, library, lecture hall, videoconferencing room, restaurant,
Pattern of use	Monday-Sunday 07:00-23:00
Required service life	Assumed to be 60 years.

Figure 11- Functional Equivalent Definition

2.2 Reference Study Period

Basically, the values for reference study period are typically greatly depends on our assumption made at initiative analysis. Because of various rules applied for LCA study; deviations of the result for the same building are inevitable. In normalization, it requires a comparison in these values in terms of specific project. In Germany, they used DNGB building labelling system to sets up the benchmark and apply it for justified comparison. While HQE Performance, concerning the LCA of 74 low-energy buildings are applied for reference period study. The different functional building with dissimilar reference study period years would have completely instinct environmental impact based on combination of module A, B and C. Hence, as to the LCA of the Henry Angus building, when we implement environmental impact exercising different Modules, we have to make preliminary assumption of the reference study period. The diverse assumption can lead to the different results and deviations.



Educational, office, hotel, residential buildings (ref. study period 50 years)	GWP [kg CO_2-Equ. /m^2*a]	ODP [kg CFC_{11}-Equ./m^2*a]	POCP [kg C_2H_4-Equ./m^2*a]	AP [kg SO_2-Equ./m^2*a]	EP [kg PO_4^{3-}-Equ./m^2*a]	PEnr [MJ/ m^2*a]	PEtot [MJ/ m^2*a]
Reference value for construction, refurbishment and EoL (Modules A1–A3, B2–B5, C, D)	**9,40**	**5,30E-07**	**0,0042**	**0,037**	**0,0047**	**123**	**151**

Industrial buildings (ref. study period 20 years)	GWP [kg CO_2-Equ. /m^2*a]	ODP [kg CFC_{11}-Equ./m^2*a]	POCP [kg C_2H_4-Equ./m^2*a]	AP [kg SO_2-Equ./m^2*a]	EP [kg PO_4^{3-}-Equ./m^2*a]	PEnr [MJ/ m^2*a]	PEtot [MJ/ m^2*a]
Reference value for construction, refurbishment and EoL (Modules A1–A3, B2–B5, C, D)	**25**	**1,0E-07**	**0,0065**	**0,06**	**0,0078**	**252**	**270**

Figure 12 - Deviations based on different reference study period in DGNB

The Henry Angus Building is assumed to be 60-year service life according to UBC guide because of insufficiency of service life requirement information. The whole building LCA system boundary is categorized into product stage (module A), construction process stage (module A), use stage (module B), end of life stage (module C) and supplementary information beyond the building life cycle (module D). But we just focus on the module A, product stage and construction process stage in Henry Angus Building LCA study. Because the other three stages have too much uncertainty, it is very difficult for the practitioner to collect or estimated data for continuing analysis, inaccurate data are bond to cause further deviations. These uncertainties contains human behavior, for example, it is impossible to estimate or control energy consumption with various individual practicing in the use stage. Regenerative methods and standards could lead to uncertainty. Improving methods for maintenance cycle and renew standard for waste processing would restrict a real world scenarios in a defied LCA model.

2.3 Object of Assessment Scope

The part of relative data about dimension of buildings is obtained from the drawings by Thompson, Berwick & Pratt in 1960’s. Experiencing two significant renovations, referring to massive activities about extension and replacement, the building’s original dimension data are inconsistent with current measurement. The façade exterior concrete walls are replaced by curtain wall, as well as that of theater. Massive partition walls were placed for individual study spaces, classrooms, meeting rooms and breakout rooms for small-group work and interviews. Additional classrooms and spaces designed and equipped for distance learning and videoconferencing. Such these improved features can not be found in the plan drawings specifically. Due to discrepancy of the quantity and quality in materials and components, the deviation from this scope needs to be clearly stated. Comparing the previous report, we identified the whole building components based on CIQS Level 3 Element, established by Canadian Institute of Quantity Surveyors to standardize building elements that enable cost analyses control on building projects.

2.3.1 Foundations

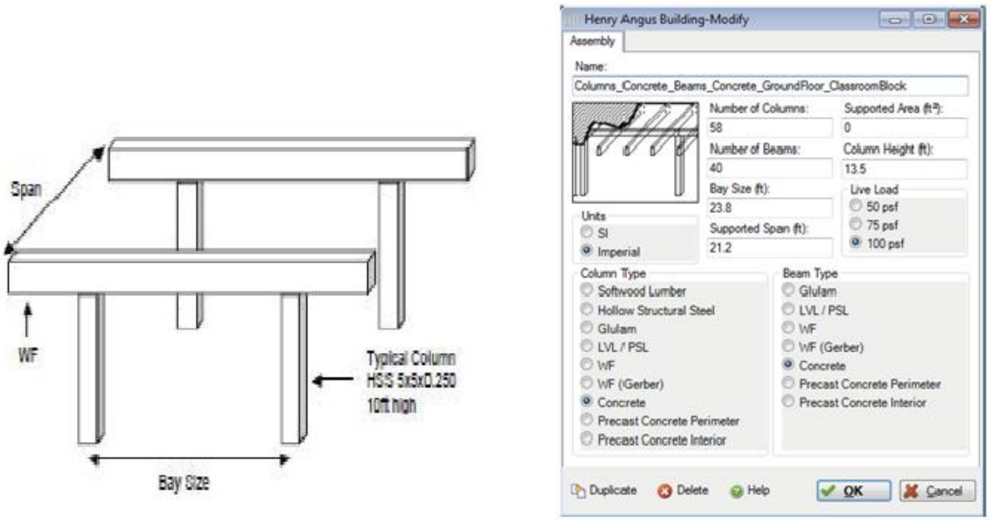
According to update CIQS, slab on grade and basement wall are excluded from foundations list. Foundation system in Henry Angus consists mainly of wall and column footings in both classroom block and office block and retaining walls. The outstanding discrepancy is that thickness of classroom block footing type A and Type B in known measures is as two times as it in EIE inputs. Most of assembly in EIE inputs obtained from Athena Estimator model and known measures form original drawings are in consistence. We got few specifications of concrete strength and fly ash proportion in concrete from drawings, these figure are explicit in the Athena Estimator. All the concrete strength for the footing was assumed 3000psi, #4 and #5 rebar are used in the foundation construction as well.

2.3.2 Floors

We identified the floors as lowest floor construction that is below the grade and upper floor construction. According to the drawings, we noticed that there are two types of slabs on grade. Because the SOG of classroom block and office block are still remain the original design, so that area of SOG was counted together rather than sections. The other type of floors includes all suspended slabs upper grade. The drawings describes the suspended slab live load was 60 psi, actually the current figure are supposed to be higher than it before because there are a lot of partition wall added into the original structure. That is the reason that we got 70 psi for the live load in the Athena Estimator model contained renewal partition walls.

2.3.3 Columns & Beams

Athena Estimator has clear identification for columns and beams. The column without beams named column_beam N/A, and column with beam is columns_beams, the database calculates column and beam dimensions in terms of quantity, bay size, support span, height. Because of renovation, additional columns and beams are not matched with that in drawings. The amount percentage indicates the columns in the basement and ground floor accounts for about 50% of total columns and beams. Concrete is the primary material for beams and columns, live load for them is 100 psi seen in Figure 13.



Name: Columns_Concrete_Beams_Concrete_GroundFloor_ClassroomBlock

Number of Columns: 58
Supported Area (ft²): 0
Number of Beams: 40
Column Height (ft): 13.5
Bay Size (ft): 23.8
Supported Span (ft): 21.2

Units
○ SI
● Imperial

Live Load
○ 50 psf
○ 75 psf
● 100 psf

Column Type
○ Softwood Lumber
○ Hollow Structural Steel
○ Glulam
○ LVL / PSL
○ WF
○ WF (Gerber)
● Concrete
○ Precast Concrete Perimeter
○ Precast Concrete Interior

Beam Type
○ Glulam
○ LVL / PSL
○ WF
○ WF (Gerber)
● Concrete
○ Precast Concrete Perimeter
○ Precast Concrete Interior

Figure 13 - Column and beams

2.3.4 Walls

The interior and exterior walls in both of classroom block and office block has altitude difference even though at the same level, on account of the discrepancy of elevation, two blocks are connected with sloping ramps. Most of partition walls can not be found in drawings, but the IE model contains all current partition walls, renovation improves the material on the interior wall, such as basement classroom block assembly components are consist of cast in place concrete with steel clad, wood clad and structural panels.

The thickness of basement classroom block and office block is around 9", concrete with fly ash associate with fiber batt cladding. The value of thickness in the drawings is much less than it in IE value might be the additional cladding on the wall after renovation. For the walls above grade in classroom block, 0.5 inches gypsum board, aluminum frame are the major material cladding on the 3000 psi concrete wall. In office block, it uses the same strength concrete as it in classroom block, but in addition to gypsum board and fiberglass batt, expanded polystyrene and vinyl siding are used as well. The envelope of classroom block used cast-in-place concrete and window opening with double glazed without coating air and aluminum window frame double pane.

2.3.4 Roof

There are two kinds of roof assembly components adopted in Henry Angus Building, 8626 sf 2.5" built up precast for the classroom block with insulation polystryene extruded organic felt 1 inch thickness. The other is suspended slab for theater, office block and penthouse. In drawings, the live load indicates 27 psi, however, the values in IE reaches to 75 and 100 psi. The variation results from overstatement in the evaluation of environmental impact, more compressive strength concrete would consume more energy for production.

In the LCA of Henry Angus Building, we just only address structure and envelope of the building. Because the material used in the structure is commonly concrete or concrete with various material cladding, this type of material would be the primary contributor for the building performance in environment. Also all the elements in the Athena EI model belong to category of structure and envelope components. In addition, quantitatively, considering two extensive refurbishments, the basic structure and envelope was extended and substituted markedly, the massive changes should be taken account into the LCI analysis. Qualitatively, the complicated materials in the structure and envelope can be tracked easily from raw material supply in the product stage to construction process stage, being the primary material used in the building construction; they also have critically important influence on the environmental impact of the building. The modified version of CIQS level 3 provides practitioners more accurate and explicit for the data classification. According the modified CIQS we reclassified the elements in the previous report in Figure 14.

CIVL 498C Level 3 Elemental Format	Description	Quantity (Amount)	Units
A11 Foundations	Total area of the slab-on-grade	1522	m^2
A21 Lowest Floor Construction	Total area of the slab-on-grade	1522	m^2
A22 Upper Floor Construction	Sum of the total area of all upper floors measured from the outside face of the exterior walls	6473	m^2
A23 Roof Construction	Sum of the total area of the roofs measured from the outside face of the exterior walls	2351	m^2
A31 Walls Below Grade	Sum of the total surface area of the exterior walls above grade	635	m^2
A32 Walls Above Grade	Sum of the total surface area of the exterior walls below grade	3280	m^2
B11 Partitions	Sum of the total surface area of the interior walls	6073	m^2

Figure 14 - Building element definition in CIQS

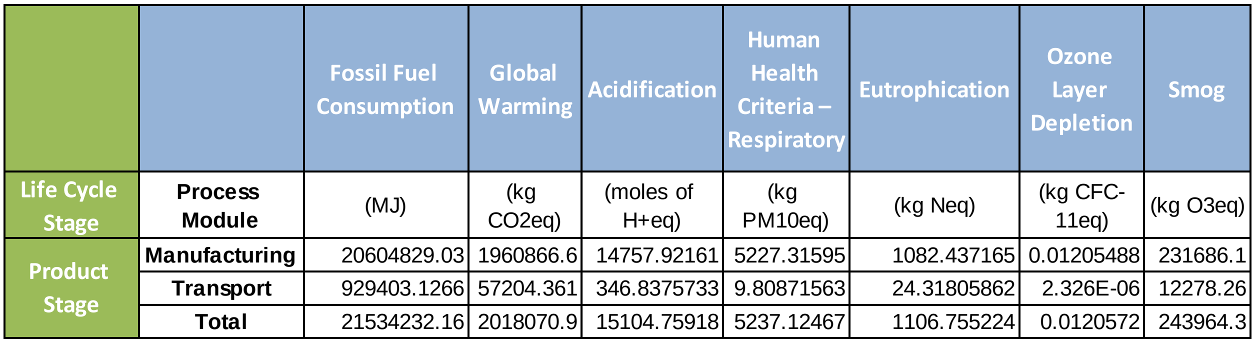
3. Statement of Boundaries and Scenarios Used in the Assessment

3.1 System Boundary

In the Henry Angus Building study includes the module A1-A3 Product Stage and Module A4-A5 Construction Process Stage. The upstream of the module A1-A3 approach focuses first on manufacturing process, we need to estimate how much fuel consumed from collecting raw material to producing the merchandise. Downstream of the process is that the amount of each waste for manufacturing the products discharge into the environment, sometime the by-products might have more effect on the environment. For the module A4-A5, we are supposed to consider the energy consumption got involved in transporting the product required in construction from supplier to construction site as the upstream. Downstream includes that the amount of energy consumption for the wasting material in construction or dealing with the disposal or recycling we need to estimate.

3.2 Product Stage

The product stage is known as “cradle to gate” in the LCA analysis, it aims to the Module A1-A3 includes three processes: raw material supply, transportation and manufacturing process. The raw material is mainly collect from the recycled and reused material gathered form previous project left. Transportation process refers to deliver the raw material to mill. Manufacturing process the process that uses the material collecting from transportation and product remanufacture or reused product for manufacturing. We can depend on the database and tool to measure environmental impact generates from these process seen in Figure15.



		Fossil Fuel Consumption	Global Warming	Acidification	Human Health Criteria – Respiratory	Eutrophication	Ozone Layer Depletion	Smog
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)	(moles of H+eq)	(kg PM10eq)	(kg Neq)	(kg CFC-11eq)	(kg O3eq)
Product Stage	Manufacturing	20604829.03	1960866.6	14757.92161	5227.31595	1082.437165	0.01205488	231686.1
	Transport	929403.1266	57204.361	346.8375733	9.80871563	24.31805862	2.326E-06	12278.26
	Total	21534232.16	2018070.9	15104.75918	5237.12467	1106.755224	0.0120572	243964.3

Figure 15 - Product Stage process environmental impacts

- Extraction of raw materials production, collection and transportation from the system border of the previous system to the production site.

  The process summarizes raw material collection phase, EI tool records the energy consumption and other impacts generates from obtaining the available material for manufacturing and co-products. Although the data from upstream and downstream process, it is counted in the product stage. For example, the wood raw material "cradle" for wood products includes all forest operation and logging.

- Manufacturing of products

  Athena database depends on the cooperation with the industries and manufactures to improve their database and get good cross-sectional industry average database and profile for each material. The manufacturing effects of that average formulation are then regionalized for each location by applying local electricity, energy and transportation grids. It is addressed to National Renewable Energy Laboratory of US Department of Energy. The reliability of the data the collect form real industry makes my study more accurate. Also we can try to establish the baseline for the manufacturing process for impairing its impacts based on the data in Figure 15.

- Generation of the energy input, including the production of the energy itself.

The consideration of production of the energy itself is necessary in my study, if nor considering the amount of energy consumption for the energy for manufacturing could underestimate the result that makes building to be more environmental friendly.

➢ Production of ancillary materials or pre-products

For the ancillary or process materials, such as production of chemical inputs, fuels and power, secondary data from LCI database were considered to be acceptable during the goal and scope development for the Henry Angus building.

➢ Packaging

In my study, the impact of packaging is deemed to be one phase of the transportation, the EI has estimated the values by comparing many manufacture's database.

➢ Transportation up to the production gate and to construction site.

It is a "gate-to-gate" product system; the Athena calculates the transportation of material based on weight the distance in which the materials are delivered from, distinguished from transportation models (e.g. diesel road, diesel rail, RFO barge, RFO ship). For example, if Henry Angus building purchases the concrete from LA, the transportation experienced RFO ship, rail way and diesel road, and each model are summed up and average to get each percentage of the region.

➢ Collection and transport of waste to disposal or to another production site.

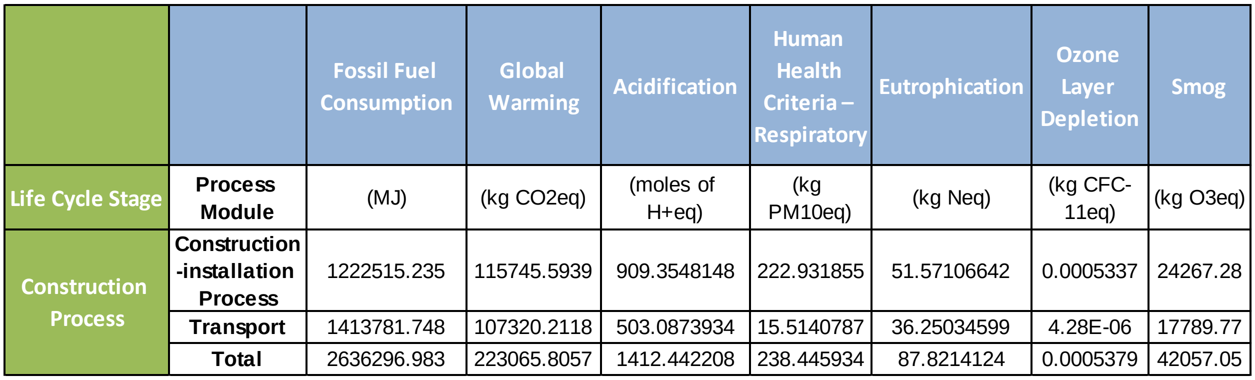
Collect and transport of disposal of the product are not got involved into the scope of my study. This process should be the module C – End of life stage, is still in the system boundary, but exceed my study boundary just contains module A1-A5.

➢ Waste management process during the product and construction stages.

Waste manage process are beyond my study system boundary.

3.3 Construction Stage

In my transport and construction installation modules is related to the transport of building products from the manufacturer’s factory (or from regional storage) to the construction site, and then install these components into the building. We analyze the building’s environmental performance in the product phase depends on the data obtained from EI seen in the Figure 16



		Fossil Fuel Consumption	Global Warming	Acidification	Human Health Criteria – Respiratory	Eutrophication	Ozone Layer Depletion	Smog
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)	(moles of H+eq)	(kg PM10eq)	(kg Neq)	(kg CFC-11eq)	(kg O3eq)
Construction Process	Construction -installation Process	1222515.235	115745.5939	909.3548148	222.931855	51.57106642	0.0005337	24267.28
	Transport	1413781.748	107320.2118	503.0873934	15.5140787	36.25034599	4.28E-06	17789.77
	Total	2636296.983	223065.8057	1412.442208	238.445934	87.8214124	0.0005379	42057.05

Figure 16 - Construction process environmental impacts

- Transportation from the manufacturing gate to the construction site

  Transportation is calculated by the distance from the plant to the construction on site associated with the different transport model as mention before. The data we got from EI can help us estimate the impacts caused by the transportation for making alternative model to mitigating its impact on environment.

- Storage of products, including provision of heating, cooling, humidity

  The energy used up in the storage is considered to be indirect consumption in the construction process.

- Installation of the product into the building (including ancillary materials) and on site transformation of construction products.

In my study, the data contains installation and transformation process, it can be used for evaluation the impact and trade off with transportation impact to reduce the total influence of the construction process on environment.

- Waste management process on the construction site and waste handling until disposal

  This process excludes from my study boundary system, but belongs to generic boundary system.

4. Environmental Data

4.1 Data Sources

- Athena LCI Database

  The Athena Institute maintained their material database through cooperating with the some industries and manufactures in cross-sectional region. Due to database are regionally sensitive, the manufacturing technology, electricity grid and recycle content are different in various regions. Although the data for product stage and construction is remaining updating, but deficiency of some material in demolition and end-of-life process have to be improved to the next generation of construction requirement. Anyway, the development of the Athena LCI data base has covered building material, energy use, and building life cycle includes the product stage, construction process, Usage stage, End-of-Life and benefits and loads beyond the system boundary.

- US LCI Database

  National Renewable Energy Laboratory of US Department of Energy (NREL) and its partner creates the US Life Cycle Inventory (LCI) database to provide individual gate-to-gate, cradle-to-gate and cradle-to-grave for both material and energy flows. The data protocol is based on ISO 14048 and financed by various stakeholders. Athena tool is embedded into Athena and US database that are most popular application in Canada and United States.

4.2 Data Adjustments and Substitution

In the LCA analysis, we compared elements in the IE inputs from previous report with its property in the Athena Estimator, identifying some discrepancy of the material type and property, the flowing are the inaccuracy description and adjustments.

- XBM_1"_lino_tile_topping

  The material type in the known measure is Lino, but the element can not be found in the Athena estimator. I assumed that the data was missing; add the element into the model for integrality in the product stage.

- Walls_Cast-in-place_GroundFloor_OfficeBlock_8"

  The material envelope in the known measure is 1 inch Styrofoam and 0.5 inch plaster, but 1 inch expanded polystyrene and o.5 inch gypsum board in IE inputs, considering the accuracy of known measure; I change the envelope of material as Styrofoam and plaster for construction stage.

- Walls_Cast-in-place_TypicalFloors_Office

  The envelope is siding plaster in known measure, but in EI model it shows gypsum board. I substitute it into siding plaster in the model for construction stage.

- Stairs_Southwest_Office_Basement_L2

The thickness of stair was reported 3 inch in the drawings, it is 12 inch of thickness in EI model, and the two renovations did not change the thickness on the southwest stair, so we change it to be 3 inch thickness in model for construction stage.

4.3 Data Quality

Data quality describes the characteristics of the data used in terms of its liability to satisfy stated requirements. The emergence of the uncertainty would diminish the validity of the assessment result. Uncertainty can refer to the lack of knowledge and inherent randomness in any model input, as following it identifies five common types of uncertainty between sources that can affect the accuracy out input.

4.3.1 Database Uncertainty

Some available database in LCA might be missing in the studied model such as Athena Estimator model. For example, varying product or project studied in the regional or temporal difference might cause database uncertainty. With the development of LCA in developing country without solid experience and knowledge about LCA, both data collection and analysis reduce the validity of life cycle assessment. The investigation in my LCA database points out this type of uncertainty as mentioned before, the element list in the drawing was missing in the EI model.

4.3.2 Model Uncertainty

As the intermediate that transfers the figure into valuable data, the model relates to the design decision and affects the quality of the assessment outputs. Simplified models with wrong function form and interactive parameter might lead to model uncertainty. Although someone came up with an approach that combined use of Economic Input / Output Life Cycle Assessment (EIO-LCA) techniques with process-based LCA has been proposed to mitigate this uncertainty, the approach do not address uncertainty with stochastic variables.

4.3.3 Temporal Uncertainty

The data of life cycle inventory will move forward to improvement after a range of years, while the process and products changes over time. Temporal uncertainty begins with the development of the materials inputs and outputs of a unit process. The evolution of the process and the products makes the uncertainty captured hardly. Although we can choose a shorter temporal validity of the assessment to reduce the temporal uncertainty, correspondingly, the approach limits the utility of the study as well. In Henry Angus Building study, there is no temporal uncertainty founded, because of long time lag between two renovations. This kind of uncertainty is likely to be caused by frequently change in current process and products.

4.3.4 Spatial Uncertainty

Practitioners seldom take account the concentration of chemicals and human population density into the LCA study and the interventions without spatial context. That introduces the spatial uncertainty into our result; technically, the emissions of the indoor and outdoor are distinct. A way to address spatial variability is to distinguish the study region into sub regions for LCA purpose. Both inventory analysis and energy assessment have to be adjusted for appropriate spatial variability. There are some limitations resisting the spatial uncertainty solution. First, insufficiency of explicit information related to regional emission. For instance, the accumulated average environmental interventions are associated with our current study; it is tough to distinguish the specific spatial environmental performance.

4.3.5 Variability Uncertainty

Variability is caused by the difference outcomes obtained from same object study using various methods, the uncertainty between sources in both inventory and energy assessment would impair the LCA outcomes. The weighting of environmental problems may introduce the variability between human preferences. Inappropriate analysis of object characteristics leads to variability such as body weight and sensitive material. The influence of variability on LCA outcomes between sources can be made operational by probabilistic simulation. When the outcome distribution of the environmental profile is reviewed and compared with the other database or documents to make all data used in analysis is precise and valid. In my study, the investigation reveals a great many of variability uncertainty. Due to the renovation some exposed material is cladding with new layer, the model investigator can not distinguish the exact composition of the element. Some different data collection methods caused the discrepancy in the model and known measured profile.

Generally, the investigation exposed some uncertainty impairs the quality of the LCI database used in my study and assessment outcome, concentrating on database uncertainty and variability. For Henry Angus Building, twice expensive renovation on structure extension and envelop substitution increase the data collection and identification. The fuzzy drawings in 1960’ are another challenge for us to eliminating the uncertainties. A way to deal with the issue is that we can integrate all drawings into one with explicit and accurate element information.

5.0 Impact Assessment

5.1 Assessment Methods

The primary impact assessment utilized in the Henry Angus LCA study was the Athena Impact Estimator developed by the Athena Sustainable Material Institute; it provides a cradle-to-grave life cycle inventory profile for the whole building. The second tool is OnCenter's OnScreen TakeOff.

Due to the previous contributions, the study directly started with the reclassified the whole building elements followed by the CIQS Level 3 rules, and then categorizes the existing building model in the EI software based on the rules. The EI focuses on establishing the community between quantities and quality of the materials and their contribution to the environment for the complete building life cycle, this study just concentrates on the product stage includes raw material supply, transportation (from suppliers to the manufacturing factory), and manufacturing and construction process stage involves transportation (from plant to construction site), and construction installation process. The other modules use stage and end-of-life stage excludes the current LCA study system boundary. The tool achieves the strategy by importing the bill of materials that indicates all material used in the building based on quantity and quality. In the end, IE filters the outcomes by a set of characteristic methodology in terms of the mid-point impact assessment established by the US Environmental Protection Agency (US EPA), a tool for the Reduction and Assessment of Chemical and other environmental Impacts (TRACI) version 2.2; available TRACI impact assessment generates the environmental impact indicator profiles a below:

- Global warming potential
- Fossil Fuel Consumption
- Acidification Potential
- Human Health Respiratory Effects Potential
- Eutrophication Potential
- Ozone Depletion Potential
- Smog Potential

5.2 Impact Categories

5.2.1 Global warming potential

Global warming potential describes the rising temperature worldwide because of greenhouse effect caused by human activity such as burning of fossil fuels and deforestation and ancillary product CO2. The measurement of global warming potential is the weight of the CO2 equivalence which is the primary factor of the greenhouse effect. The GWP value depends on how the gas concentration decays over time in the atmosphere. This is often not precisely known and hence the values should not be considered exact. Its endpoints include agricultural influence and tropical storms.

5.2.2 Fossil Fuel Consumption potential

Fossil fuel consumption (coal and natural gas) describes the total energy amount generates from the activities related to material manufacturing, transportation and construction in the study. They account for approximately 80% of global energy and lead to severe impacts includes emission of ecologically damaging to human health and air pollution. The category indicates is mega joules (MJ) that released form resources.

5.2.3 Acidification Potential

Acidification potential describes that acid gas released into the air or resulting from reaction of non-acid components of the emission reacts with water and transformer to the air pollution. It leads to a decrease in the pH value of rainwater and fog from 5.6-4. This damage ecosystem, whereby forest dies back is most serious impact. Acidification has direct and indirect impacts for example nutrient being wash out of soil or increase solubility of metal in soil, even corrode the building materials.

5.2.4 Human Health Respiratory Effects Potential

The criteria requires that the weight of air particle substance should be less than 10 µm (kg PM10 eq) respiratory health can be effected by the emission matter from industry or climate change. In this study, it is more likely to evaluate the emission release from the production and construction of the materials used in the building.

5.2.5 Eutrophication Potential

Eutrophication potential describes an increase in the rate of supply of organic matter in ecosystem by calculating the phosphate equivalents. Due to the increased generation of biomass and the consequently heavier sedimentation of dead organic material, the oxygen dissolved in deep water is consumed faster, through aerobic decomposition. This can lead to serious damage in the biological populations inhabiting the sediment. In addition to this, direct toxic effects on higher organisms, including humans must be taken into account when certain species of algae appear in mass. The overuse of this type of material will effect generates toxicity to human and aquatic mammals.

5.2.6 Ozone Depletion Potential

The ozone depletion potential of a chemical compound is the realse amount of degradation to the ozone layer it can cause. ODP is often applied in measurement combination of global warming potential. The ozone depletion potential increased with the heavier halogens since the C-X bond strength is lower. The most importance of Ozone depletion formation is the lower atmosphere is photo dissociation of NO2.

5.2.7 Smog Potential

The Smog Potential is a phenomenon that the emission release from industries and transportation aggregate at the ground level due to specific air condition. It brings out some human health issue such as emphysema, bronchitis and asthma; it is measured by the amount of O3 equivalent.

6. Model Development

6.1 Establish the level 3 model

The Canadian Institute of Quantity Surveyors (CIQS) established a set of standards to category the whole building components for cost analysis and control purpose, it defines four different levels of aggregation to present the building as follows:

Level 1 elements are referred to as “Major Group Elements”

Level 2 elements are referred to as “Group Elements”

Level 3 elements are referred to as “Elements”

Level 4 elements are referred to as “Sub-Elements”

The elements data can be found in both original drawings and EI model. Drawings contain most specification on elements in classroom block and office block. But it just presents the preliminary design components and specification, expansions and improving elements excludes from the drawings. The other access to get these explicit elements includes type, property and geometry measurement is from model in the Athena Impact Estimator. All elements are re-categorized into element level 3 as following.

A11.Foundations. It includes standard foundation with the wall and column footings, pile caps crawl space walls etc. the basement wall excludes from A11

A21.Lowest Floor Construction includes slabs on grade. There are two type of slabs on found in database.

A31.Upper Floor Construction contains upper construction with structural frame, suspended floor, expansion and joints etc., Column & Beams that was defined as one isolated category before, and stair construction.

A23. Roof Construction involves roof structural component and columns & beams supporting roofs.

A31.Walls Below Grade, includes wall below grade and structural wall below grade. Applied finishes (paint) to interior face of exterior walls is excluded.

A32. Walls Above Grade, contains all exterior walls above grade and curtain walls.

B11. Partitions include all interior wall (movable and structural) and doors.

6.2 Bill of Material Process

After finishing CIQS Level 3 Element category in the IE inputs document and Impact Estimator model, I saved all level 3 elements isolated EI files for creating separate bill of materials that can show clearly each material contained in the element in quantity and quality.

A reference flow is a quantified amount of the product(s), including product parts, necessary for a specific product system to deliver the performance described by the functional unit. The purpose of the reference flows is to translate the abstract functional unit into specific product flows for each of the compared systems

Material	Quantity	Unit
#15 Organic Felt	9812.161	m2
1/2" Regular Gypsum Board	1815.9831	m2
Aluminum	28.6062	Tonnes
Ballast (aggregate stone)	130500.0203	kg
Commercial(26 ga.) Steel Cladding	406.7295	m2
Concrete 20 MPa (flyash av)	5825.0437	m3
Concrete 30 MPa (flyash av)	927.5742	m3
Concrete Blocks	381.2866	Blocks
Double Glazed No Coating Air	568.3393	m2
EPDM membrane (black, 60 mil)	1464.1974	kg
Expanded Polystyrene	622.2303	m2 (25mm)
Extruded Polystyrene	1856.7407	m2 (25mm)
FG Batt R11-15	5821.2865	m2 (25mm)
Galvanized Sheet	2.7778	Tonnes
Glazing Panel	0.7098	Tonnes
Joint Compound	1.8124	Tonnes
Mortar	7.2662	m3
Nails	1.8905	Tonnes
Paper Tape	0.0208	Tonnes
Polyethylene Filter Fabric	0.1757	Tonnes
Precast Concrete	301.1364	m3
Rebar, Rod, Light Sections	470.3985	Tonnes
Roofing Asphalt	15340.6144	kg
Small Dimension Softwood Lumber, kiln-dried	7.068	m3
Solvent Based Alkyd Paint	1.4739	L
Vinyl Siding	8154.8197	m2
Water Based Latex Paint	138.0056	L
Welded Wire Mesh / Ladder Wire	5.2542	Tonnes

Figure 17 – Building Bill of Materials

Material	Quantity	Unit
1/2" Regular Gypsum Board	20.8474	m2
Concrete 20 MPa (flyash av)	251.867	m3
FG Batt R11-15	39.1319	m2 (25mm)
Joint Compound	0.0208	Tonnes
Nails	0.0014	Tonnes
Paper Tape	0.0002	Tonnes
Rebar, Rod, Light Sections	4.766	Tonnes

Figure 18 - A11 Foundations Bill of Materials

Material	Quantity	Unit
Concrete 20 MPa (flyash av)	319.5007	m3
Welded Wire Mesh / Ladder Wire	1.3749	Tonnes

Figure 19 - A21 Lowest Floor Construction Bill of Materials

Material	Quantity	Unit
Concrete 20 MPa (flyash av)	1336.1209	m3
Concrete 30 MPa (flyash av)	899.5553	m3
Precast Concrete	252.0628	m3
Rebar, Rod, Light Sections	357.4676	Tonnes
Welded Wire Mesh / Ladder Wire	3.1933	Tonnes

Figure 20 - A22 Upper Floor Construction Bill of Materials

Material	Quantity	Unit
#15 Organic Felt	28338.0757	m2
Ballast (aggregate stone)	412105.3272	kg
Concrete 20 MPa (flyash av)	229.0936	m3
Concrete 30 MPa (flyash av)	28.0189	m3
Concrete Blocks	381.2866	Blocks
Expanded Polystyrene	319.9127	m2 (25mm)
Extruded Polystyrene	1856.7407	m2 (25mm)
Galvanized Sheet	2.4682	Tonnes
Mortar	1.211	m3
Polyethylene Filter Fabric	0.4218	Tonnes
Precast Concrete	49.0736	m3
Rebar, Rod, Light Sections	16.3113	Tonnes
Roofing Asphalt	23010.9216	kg
Welded Wire Mesh / Ladder Wire	0.6859	Tonnes

Figure 21 - A22 A23 Roof Construction Bill of Materials

Material	Quantity	Unit
Concrete 20 MPa (flyash av)	195.1266	m3
FG Batt R11-15	1031.4504	m2 (25mm)
Nails	0.0309	Tonnes
Rebar, Rod, Light Sections	3.4091	Tonnes

Figure 22 - A31 Walls Below Grade Bill of Materials

Material	Quantity	Unit
#15 Organic Felt	366.1358	m2
1/2" Regular Gypsum Board	327.0517	m2
Aluminum	110.4891	Tonnes
Concrete 20 MPa (flyash av)	1077.8176	m3
Double Glazed No Coating Air	2154.4797	m2
EPDM membrane (black, 60 mil)	5686.9029	kg
Expanded Polystyrene	103.2258	m2 (25mm)
FG Batt R11-15	2094.4579	m2 (25mm)
Galvanized Sheet	0.1238	Tonnes
Glazing Panel	0.2028	Tonnes
Joint Compound	0.3264	Tonnes
Nails	4.9263	Tonnes
Paper Tape	0.0037	Tonnes
Rebar, Rod, Light Sections	19.5721	Tonnes
Solvent Based Alkyd Paint	0.5896	L
Vinyl Siding	353.2773	m2

Figure 23 - A32 Walls Above Grade Bill of Materials

Material	Quantity	Unit
1/2" Regular Gypsum Board	1468.084	m2
Aluminum	3.1006	Tonnes
Concrete 20 MPa (flyash av)	2415.5173	m3
Double Glazed No Coating Air	118.8775	m2
EPDM membrane (black, 60 mil)	169.8867	kg
Expanded Polystyrene	202.3469	m2 (25mm)
FG Batt R11-15	2656.2462	m2 (25mm)
Galvanized Sheet	0.4953	Tonnes
Glazing Panel	1.2168	Tonnes
Joint Compound	1.4652	Tonnes
Nails	1.0811	Tonnes
Paper Tape	0.0168	Tonnes
Rebar, Rod, Light Sections	44.203	Tonnes
Small Dimension Softwood Lumber, kiln-dried	14.136	m3
Solvent Based Alkyd Paint	2.3582	L
Water Based Latex Paint	276.0112	L

Figure 24 - B11 Partitions Bill of Materials

6.3 Assessment Process

The assessment outcome depends on the combination of Construction drawings, Inputs and Assumption, OnScreen Takeoff tool, and Impact Estimator model. The framework of the mechanism for these tools used in impact assessment is shown below:

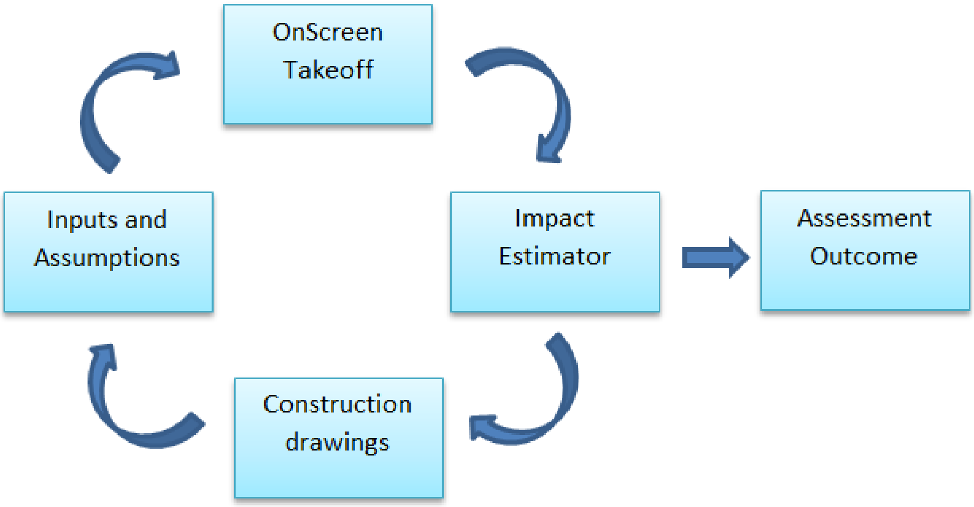


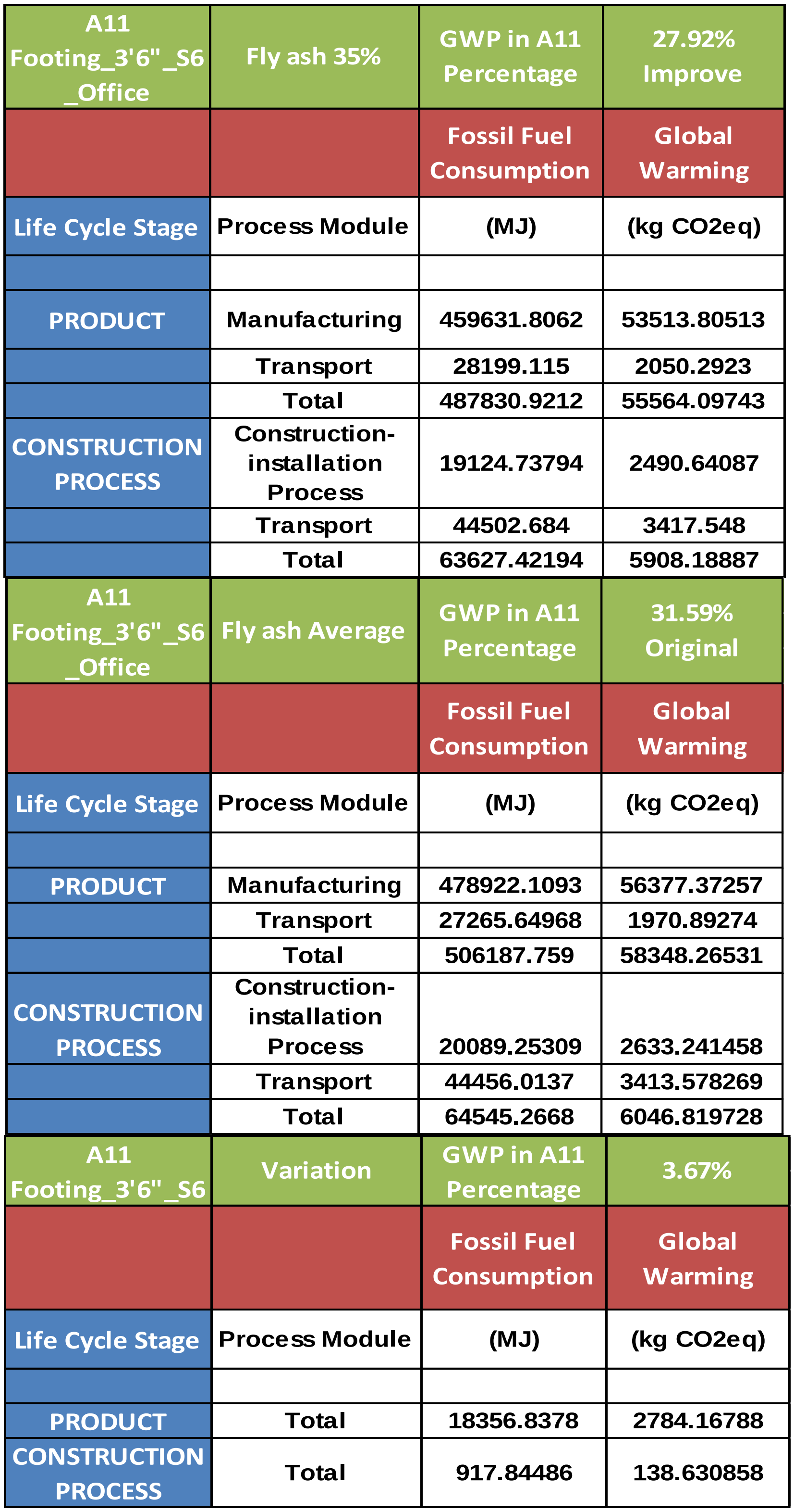
Figure 25 - Assessment Framework

The process started with practitioners extract the elements of the building from Impact Estimator and compared it with the construction drawings for accuracy and data completeness purpose. The summarized data will re-categorized based on CIQS level 3 elements seen in the Annex D. there are two types of inputs representation of each elements, IE inputs and know measured obtained from the Athena Impact Estimator and drawings respectively. Variations and discrepancy on property and geometry measurement reveals that our model exists uncertainties that could impair the outcome validity. Thus, investigation was implemented to review these uncertainties through comparing these type and property inaccuracies and geometry measurement inaccuracies among Athena EI model, original drawings, and OnScreen Takeoff tool. As the Fig. 17 shows that the whole the first assess step is improving the data accuracy and validity as far as possible. After identifying the specific elements, I made some improvements strategies for them including change the type and geometry based on comparison of all available tools and documents, then put them back to the new model with improvements. Hence, the improvements strategy conducts two outcomes, original model and improved model. Due to the global warming potential is the most indicators in assessing building environmental performance, the study filtered some relative sensitive sub elements that have more contribution on the GWP in the EI model for each Level 3 Element, the higher percentage value presents, the more effect on GWP they have in the each level. Considering their sensitivity on the GWP, it is necessary for us to figure out some improvements to diminish their impact on GWP, so the study achieve our goal by improving the property of elements. For example, we assume that some concrete component with 100MPa psi compressive strength to be 60MPa, the decreasing strength will cut down energy consumption and lower emission form production stage to construction stage. The practitioner can compare these outcomes to understand how their building works in the aspect of environment and energy consumption.

6.4 Model Improvements

As mentioned above the assessment process is more likely an iterative comparison, investigation, and improvement process, the input data experiences the revise and updates in each scenario, then the study derives some inaccuracy and discrepancy data used for improving the final model. The following are some data discovered in the assessment process needs to be improve for the model validity and preciseness. The methodology used in the investigation these inaccurate data is considering the Global Warming Potential as the reference criteria. Since most practitioners regards the building GWP performance to be the main objective for improvement, the study scales the percentage of GWP in the Impact Estimator based on CIQS level 3 elements and pick up some “GWP-oriented Contributor” element, then compared with their property and type in the “Known Measure input” document, the improvements are finalized by swapping the property of these element in the Estimator model in line with its value in known measure or GWP reduction assumption. The following figure indicates the improvement for each level.

- A11 foundations. Footing_3'6"_S6_Office takes up the 31.59% GWP impact in A11 element. The concrete specification is just described in the IE inputs, so the study assumed the concrete in practice contains 35% flyash, the substitution reduced the its GWP to 27.92% preference to environment.



A11 Footing_3'6"_S6 _Office	Fly ash 35%	GWP in A11 Percentage	27.92% Improve
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	459631.8062	53513.80513
	Transport	28199.115	2050.2923
	Total	487830.9212	55564.09743
CONSTRUCTION PROCESS	Construction-installation Process	19124.73794	2490.64087
	Transport	44502.684	3417.548
	Total	63627.42194	5908.18887

A11 Footing_3'6"_S6 _Office	Fly ash Average	GWP in A11 Percentage	31.59% Original
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	478922.1093	56377.37257
	Transport	27265.64968	1970.89274
	Total	506187.759	58348.26531
CONSTRUCTION PROCESS	Construction-installation Process	20089.25309	2633.241458
	Transport	44456.0137	3413.578269
	Total	64545.2668	6046.819728

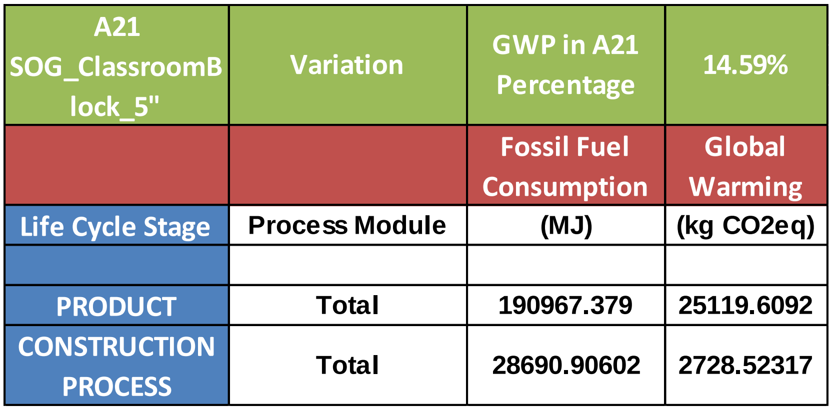
A11 Footing_3'6"_S6	Variation	GWP in A11 Percentage	3.67%
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Total	18356.8378	2784.16788
CONSTRUCTION PROCESS	Total	917.84486	138.630858

Figure 26 - A11 Foundations Improvement

- A21 Lowest Floor Construction. The SOG_ClassroomBlock_5" accounts for 74.03% with 200mm of thickness in EI model; it is described 100mm in drawings. The improvement changed it to be 100, causing causing 14.9% reduction in GWP

A21 SOG_ClassroomBlock_5"	Tickness 200mm	GWP in A21 Percentage	74.03% Original
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	515020.4588	67713.008
	Transport	33511.05338	2420.22673
	Total	548531.5122	70133.2347
CONSTRUCTION PROCESS	Construction-installation Process	24781.88573	3318.19114
	Transport	53846.05379	4134.26302
	Total	78627.93952	7452.45417

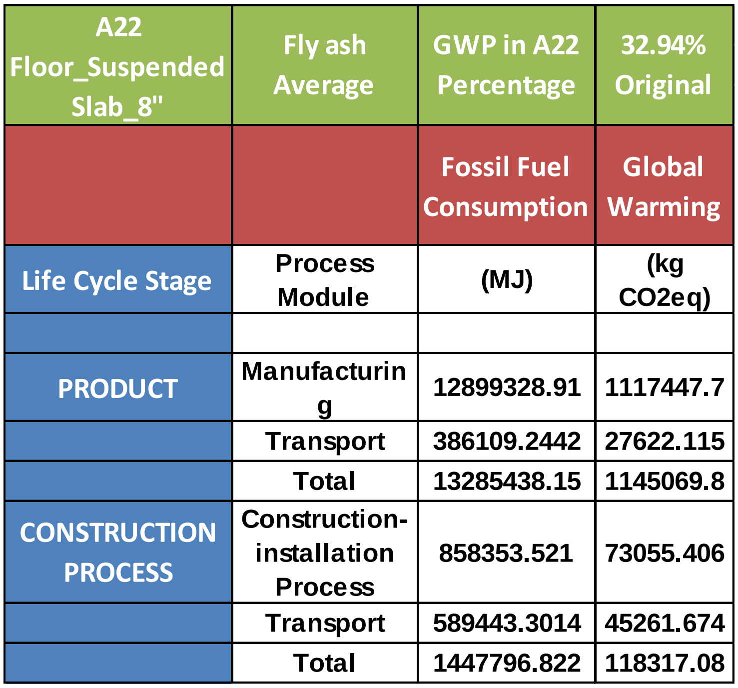
A21 SOG_ClassroomBlock_5"	Tickness 100mm	GWP in A21 Percentage	59.44% Improve
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	336333.6342	43480.0791
	Transport	21230.499	1533.5464
	Total	357564.1332	45013.6255
CONSTRUCTION PROCESS	Construction-installation Process	15847.5445	2106.5447
	Transport	34089.489	2617.3863
	Total	49937.0335	4723.931



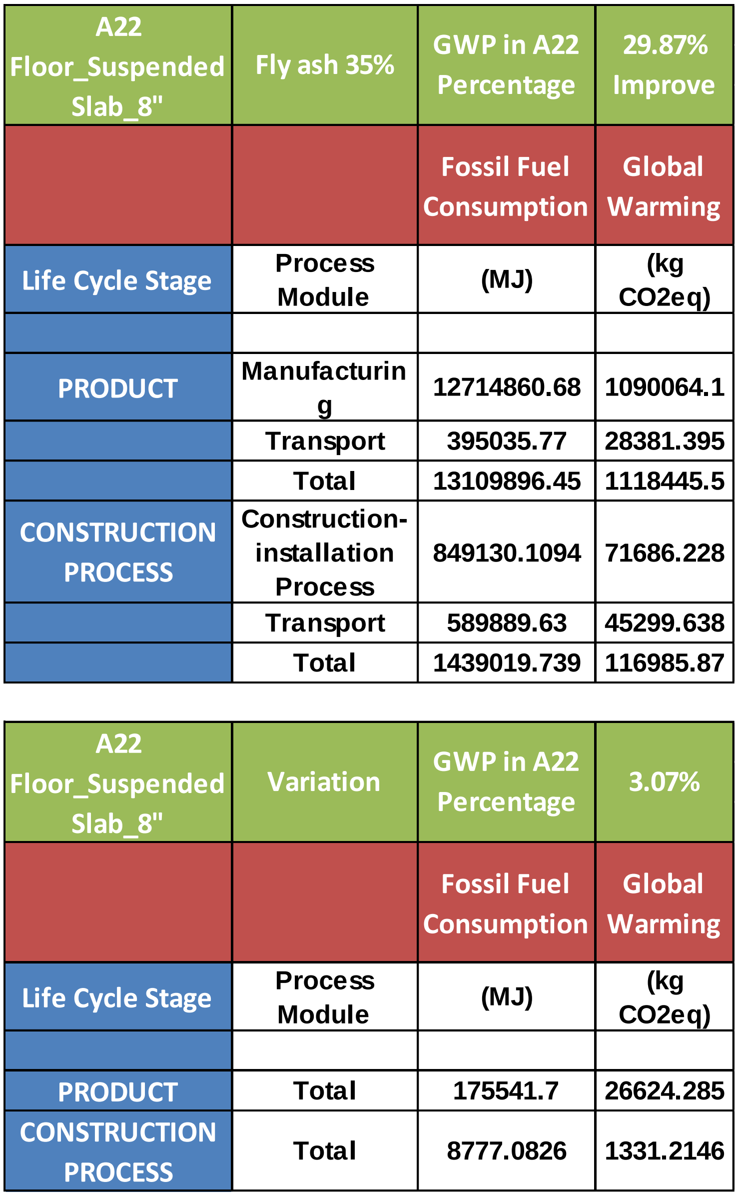
A21 SOG_ClassroomBlock_5"	Variation	GWP in A21 Percentage	14.59%
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Total	190967.379	25119.6092
CONSTRUCTION PROCESS	Total	28690.90602	2728.52317

Figure 27 - A21 Lowest Floor Construction

- A22 Upper Floor Construction. In this element, Floor_SuspendedSlab_8" contributes in the GWP is 14.95% in the model, considering no description in the known measure input and friendly environmental material, the improvements adjusted it from average to 35% flyash, leading to 3.07% decrease.



A22 Floor_Suspended Slab_8"	Fly ash Average	GWP in A22 Percentage	32.94% Original
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	12899328.91	1117447.7
	Transport	386109.2442	27622.115
	Total	13285438.15	1145069.8
CONSTRUCTION PROCESS	Construction-installation Process	858353.521	73055.406
	Transport	589443.3014	45261.674
	Total	1447796.822	118317.08

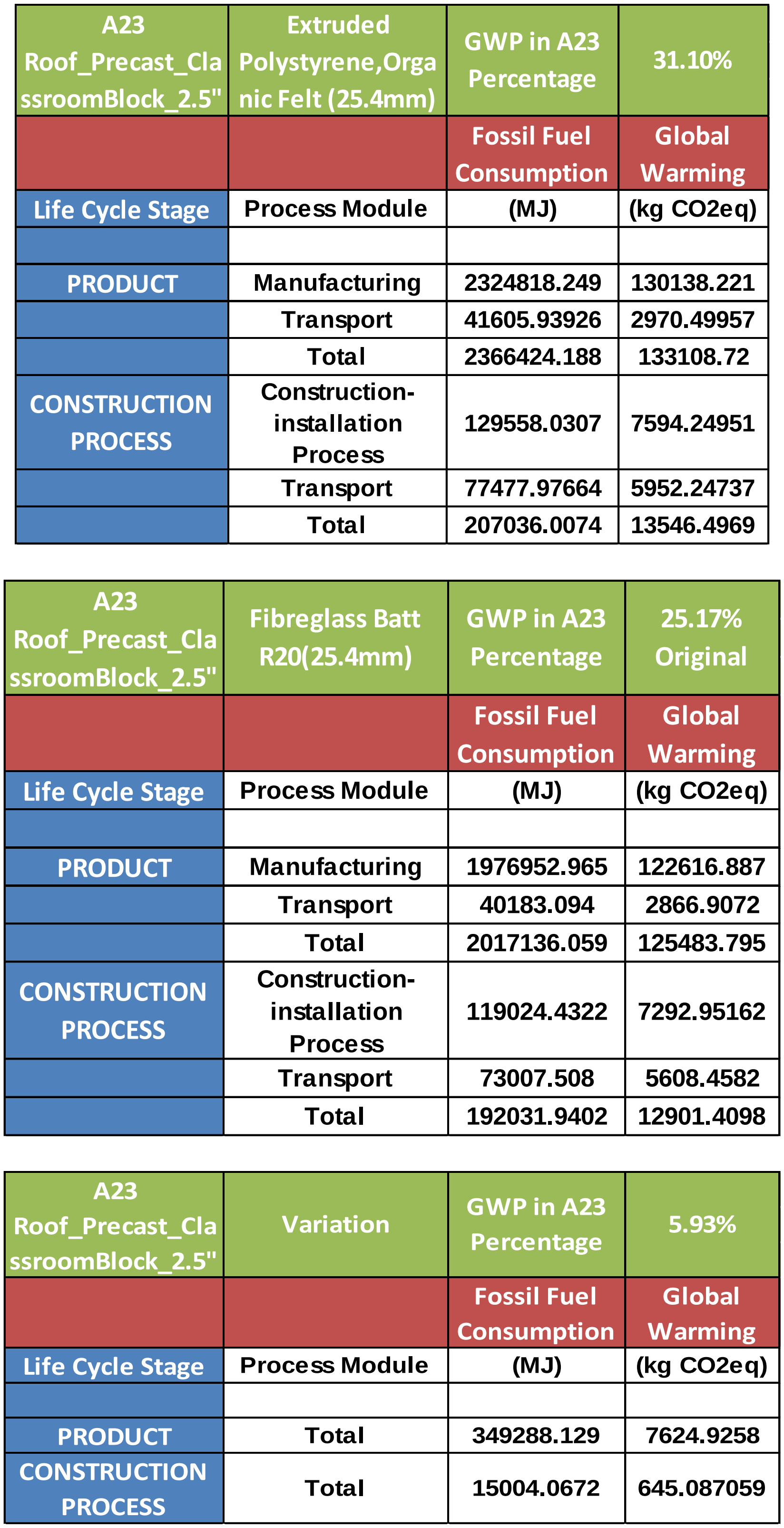


A22 Floor_Suspended Slab_8"	Fly ash 35%	GWP in A22 Percentage	29.87% Improve
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	12714860.68	1090064.1
	Transport	395035.77	28381.395
	Total	13109896.45	1118445.5
CONSTRUCTION PROCESS	Construction-installation Process	849130.1094	71686.228
	Transport	589889.63	45299.638
	Total	1439019.739	116985.87

A22 Floor_Suspended Slab_8"	Variation	GWP in A22 Percentage	3.07%
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Total	175541.7	26624.285
CONSTRUCTION PROCESS	Total	8777.0826	1331.2146

Figure 28 - A22 Upper Floor Construction

- A23 Roof Construction. The assessment study found Roof_Precast_ClassroomBlock_2.5" had most impact on GWP 31.10% in the level, the discrepancy was found in the measure input, grid insulation. But this material can not be in the material list in the model, thus, improvements assumed it to be Fibreglass Batt R20 (25.4mm), a slight 5.93% deduction in GWP.



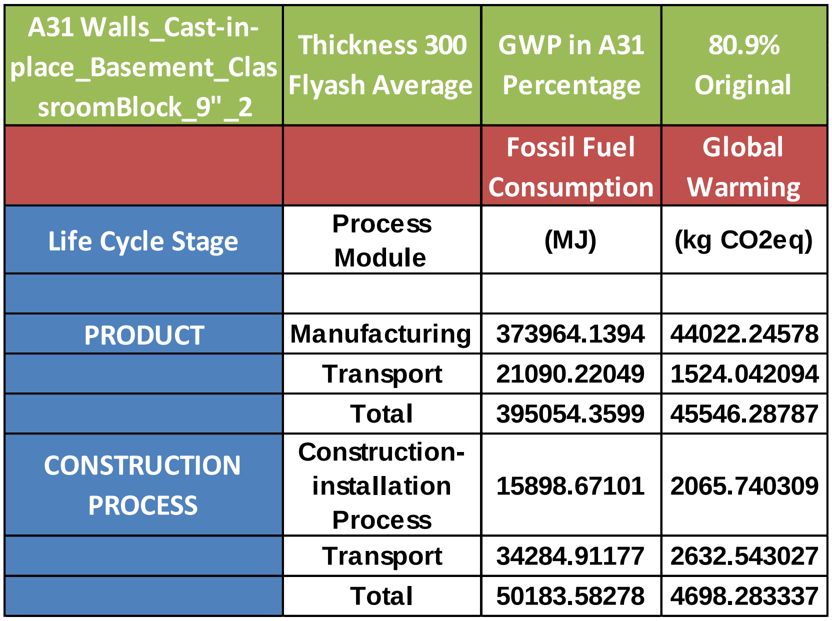
A23 Roof_Precast_ClassroomBlock_2.5"	Extruded Polystyrene,Organic Felt (25.4mm)	GWP in A23 Percentage	31.10%
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	2324818.249	130138.221
	Transport	41605.93926	2970.49957
	Total	2366424.188	133108.72
CONSTRUCTION PROCESS	Construction-installation Process	129558.0307	7594.24951
	Transport	77477.97664	5952.24737
	Total	207036.0074	13546.4969

A23 Roof_Precast_ClassroomBlock_2.5"	Fibreglass Batt R20(25.4mm)	GWP in A23 Percentage	25.17% Original
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	1976952.965	122616.887
	Transport	40183.094	2866.9072
	Total	2017136.059	125483.795
CONSTRUCTION PROCESS	Construction-installation Process	119024.4322	7292.95162
	Transport	73007.508	5608.4582
	Total	192031.9402	12901.4098

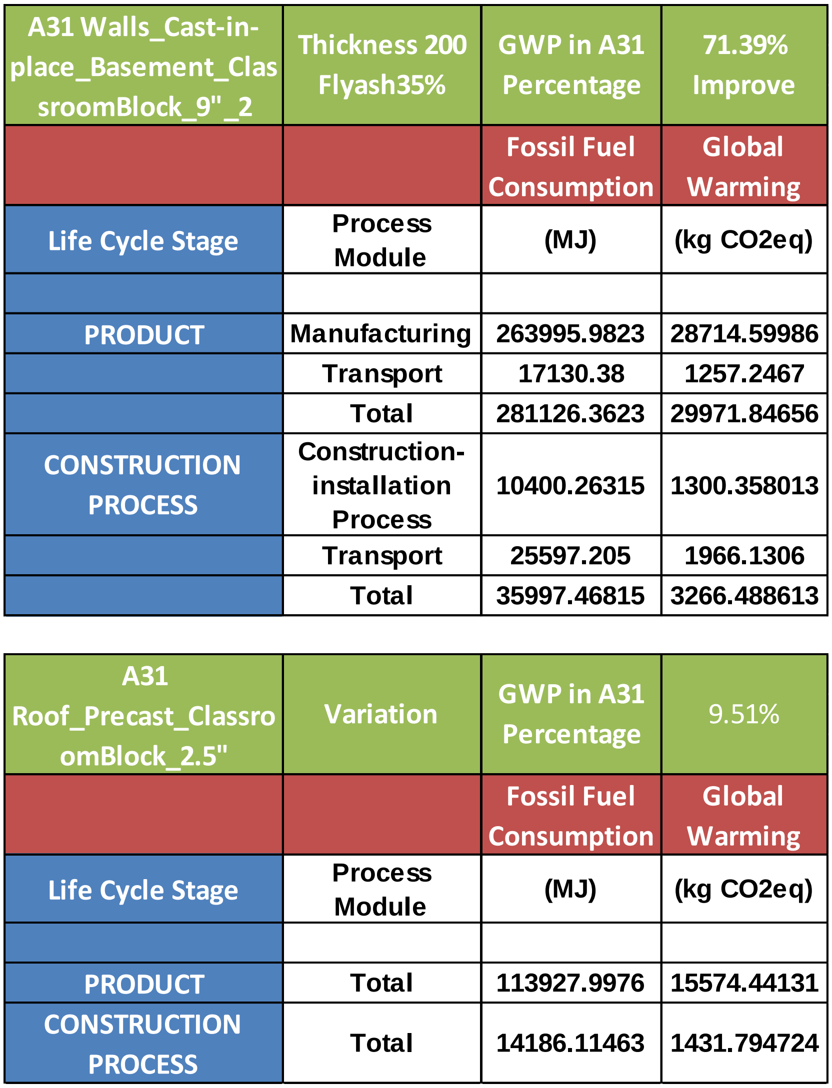
A23 Roof_Precast_ClassroomBlock_2.5"	Variation	GWP in A23 Percentage	5.93%
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Total	349288.129	7624.9258
CONSTRUCTION PROCESS	Total	15004.0672	645.087059

Figure 29 - A23 Roof Construction

- A31 Walls Below Grade. Basically, Walls_Cast-in-place_Basement_ClassroomBlock_9"_2 hold the major GWP impact in this level 80.9%, the thickness in measure input is 200mm, the original model values it 300mm, thus the study changes the model as the measure value. With a view to the thicker might not support the addition structure and envelope after renovation, the concrete fly ash average was changed to be with 35% flyash.



A31 Walls_Cast-in-place_Basement_ClassroomBlock_9"_2	Thickness 300 Flyash Average	GWP in A31 Percentage	80.9% Original
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	373964.1394	44022.24578
	Transport	21090.22049	1524.042094
	Total	395054.3599	45546.28787
CONSTRUCTION PROCESS	Construction-installation Process	15898.67101	2065.740309
	Transport	34284.91177	2632.543027
	Total	50183.58278	4698.283337



A31 Walls_Cast-in-place_Basement_ClassroomBlock_9"_2	Thickness 200 Flyash35%	GWP in A31 Percentage	71.39% Improve
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	263995.9823	28714.59986
	Transport	17130.38	1257.2467
	Total	281126.3623	29971.84656
CONSTRUCTION PROCESS	Construction-installation Process	10400.26315	1300.358013
	Transport	25597.205	1966.1306
	Total	35997.46815	3266.488613

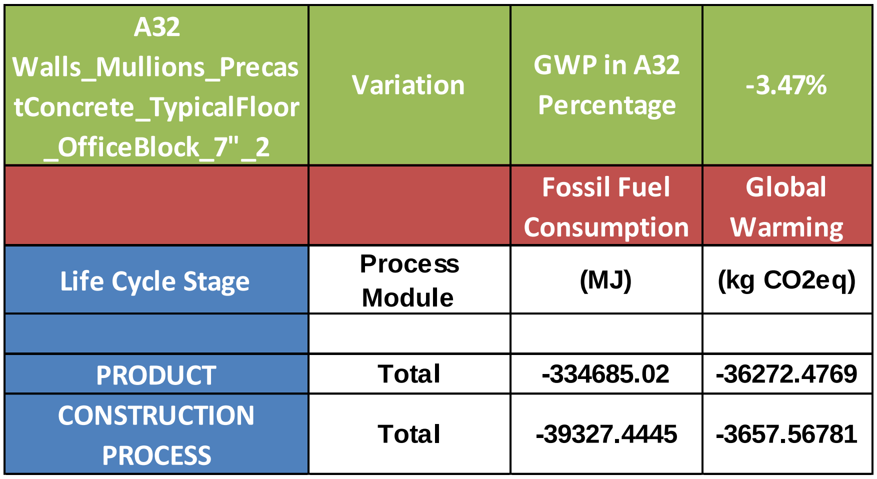
A31 Roof_Precast_ClassroomBlock_2.5"	Variation	GWP in A31 Percentage	9.51%
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Total	113927.9976	15574.44131
CONSTRUCTION PROCESS	Total	14186.11463	1431.794724

Figure 30 - A31 Walls Below Grade

- A32 Walls Above Grade. The length and thickness variation of Walls_Mullions_PrecastConcrete_TypicalFloor_OfficeBlock_7"_2 resulted in underestimating its impact 3.47%, the improvement adjusted it to real value in the EI model.

A32 Walls_Mullions_PrecastConcrete_TypicalFloor_OfficeBlock_7"_2	Length 127m Thickness 300mm	GWP in A32 Percentage	17.61% Original
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	4298624.78	413815.3559
	Transport	123998.1299	8709.990709
	Total	4422622.91	422525.3467
CONSTRUCTION PROCESS	Construction-installation Process	97063.41183	11735.01808
	Transport	207378.87	15925.81256
	Total	304442.2818	27660.83064

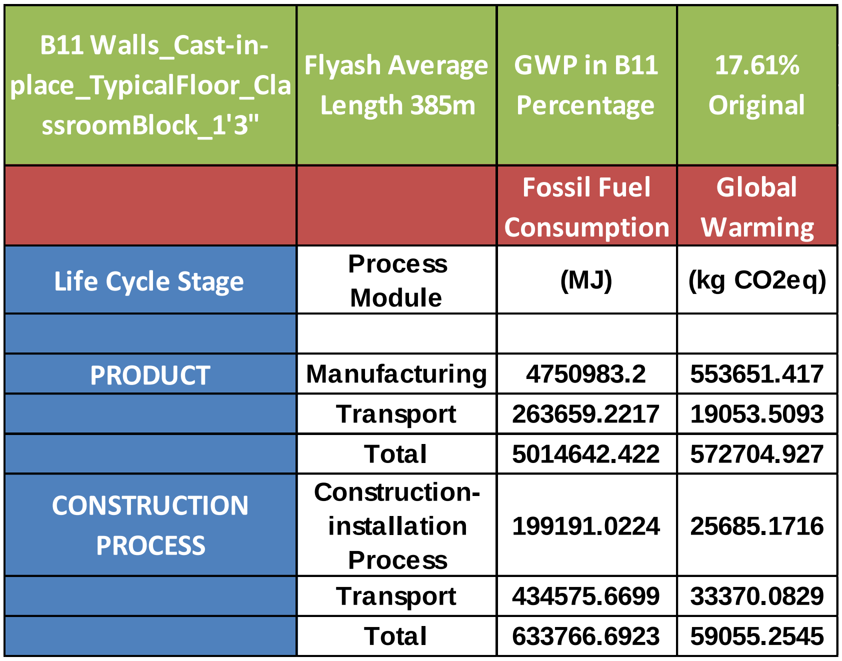
A32 Walls_Mullions_PrecastConcrete_TypicalFloor_OfficeBlock_7"_2	Length 435m Thickness 200mm	GWP in A32 Percentage	21.08% Improve
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	4616748	448889.9111
	Transport	140559.93	9907.9125
	Total	4757307.93	458797.8236
CONSTRUCTION PROCESS	Construction-installation Process	109274.2663	13310.33045
	Transport	234495.46	18008.068
	Total	343769.7263	31318.39845



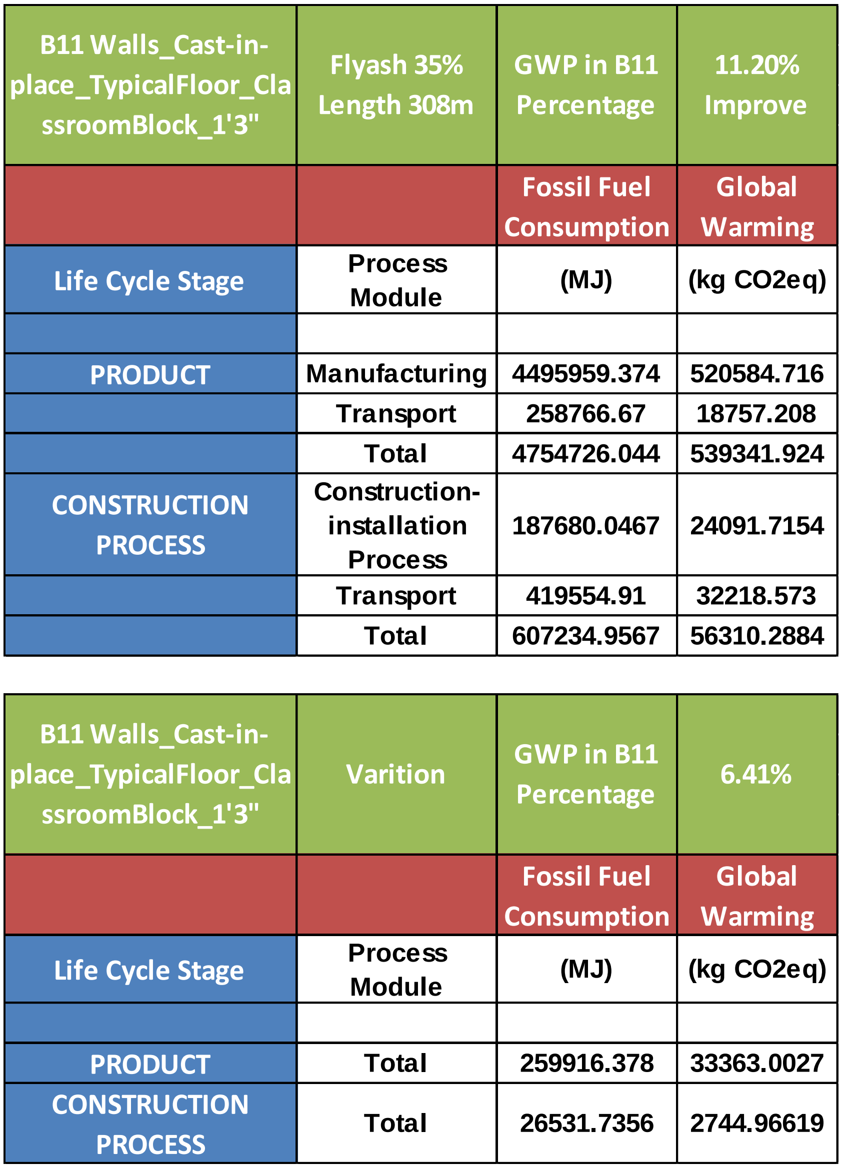
A32 Walls_Mullions_PrecastConcrete_TypicalFloor_OfficeBlock_7"_2	Variation	GWP in A32 Percentage	-3.47%
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Total	-334685.02	-36272.4769
CONSTRUCTION PROCESS	Total	-39327.4445	-3657.56781

Figure 31 - A32 Walls Above Grade

- B11 Partitions. Walls_Cast-in-place_TypicalFloor_ClassroomBlock_1'3" has difference length in both IE and measure inputs, comparing with drawings, the real length should be 308m, the study also assumed it with 35% flyash concrete. The GWP percentage reduced by 6.41%



B11 Walls_Cast-in-place_TypicalFloor_ClassroomBlock_1'3"	Flyash Average Length 385m	GWP in B11 Percentage	17.61% Original
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	4750983.2	553651.417
	Transport	263659.2217	19053.5093
	Total	5014642.422	572704.927
CONSTRUCTION PROCESS	Construction-installation Process	199191.0224	25685.1716
	Transport	434575.6699	33370.0829
	Total	633766.6923	59055.2545



B11 Walls_Cast-in-place_TypicalFloor_ClassroomBlock_1'3"	Flyash 35% Length 308m	GWP in B11 Percentage	11.20% Improve
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Manufacturing	4495959.374	520584.716
	Transport	258766.67	18757.208
	Total	4754726.044	539341.924
CONSTRUCTION PROCESS	Construction-installation Process	187680.0467	24091.7154
	Transport	419554.91	32218.573
	Total	607234.9567	56310.2884

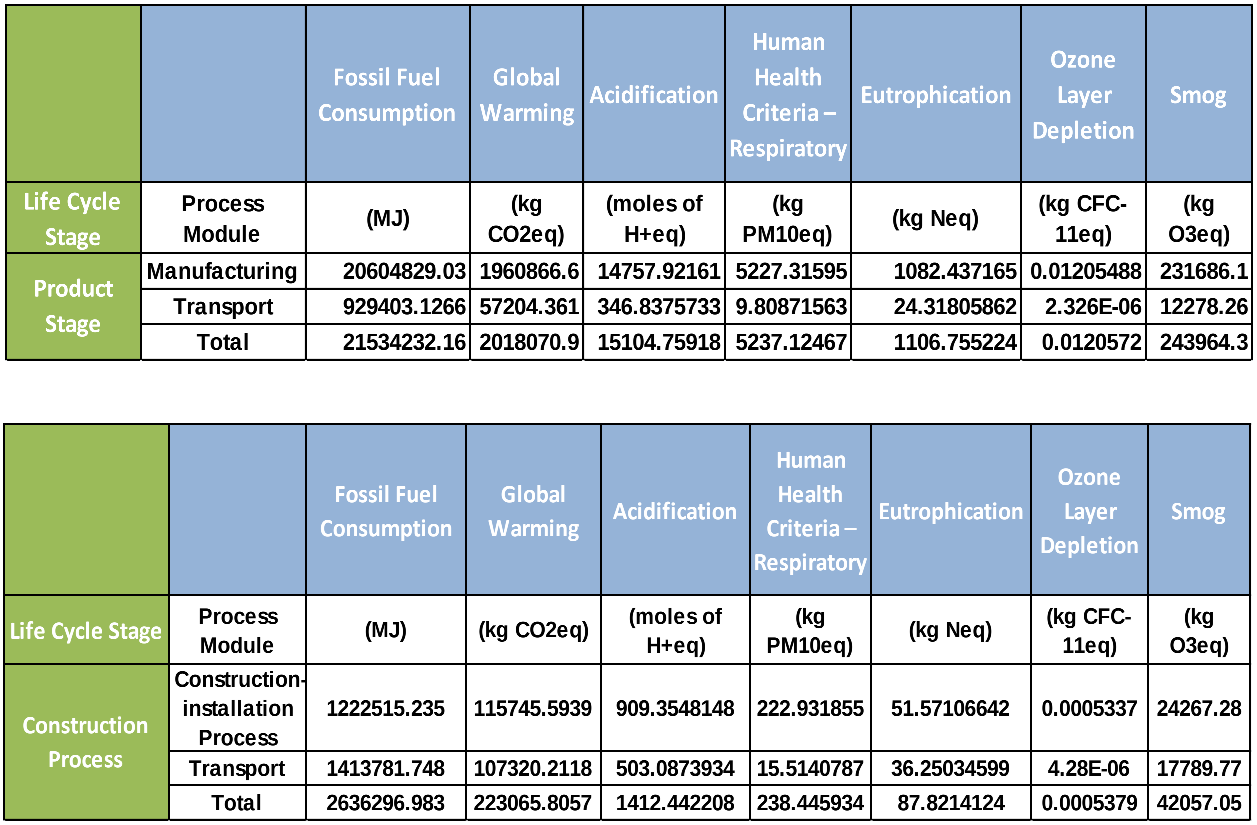
B11 Walls_Cast-in-place_TypicalFloor_ClassroomBlock_1'3"	Varition	GWP in B11 Percentage	6.41%
		Fossil Fuel Consumption	Global Warming
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)
PRODUCT	Total	259916.378	33363.0027
CONSTRUCTION PROCESS	Total	26531.7356	2744.96619

Figure 32 - B11 Partitions

7.0 Communication of Assessment Results

7.1 Life Cycle Result

The assessment of Henry Angus Building experiences data collection and sort, comparison, improvement and building declaration in the end. One of building results contains Henry Angus environmental impact result that will be showed in the Annex A, associated with UBC buildings benchmark for understanding Henry Angus performance among the "neighbours" on campus based on each environmental category indicator. The building result indicates that the values of each impact category indicator decrease progressively as manufacturing process, construction-installation process and transport process see in the Fig.33 It means that we can control the building performance as long as the decrease the impact in product stage. The other important is building model improvement as showed above. The process re-evaluates the building performance by identifying the GWP contributor and swapping its material and adjusting dimension, the result after improvement is encouraging, with GWP impact decrease more or less, except A32 improvement, the actual dimension increases its GWP proportion. Some favourable results owed to the assumption, for example IE inputs indicate some concrete with average flyash, the study changed it to be higher flyash compound 35%, as we known, the flyash does not only reduces energy consumption during product stage but also increase the concrete strength. The improvement of seven hotspots elements optimizes our building environmental impact as well. I think the model improvement is not a part of the EN 15978 requirements; it is more likely breaking down the model based on CIQS rules and identifies the GWP sensitivity element and evaluate its validity and accuracy compared with measure inputs, however, it provides participants with more accurate building model, alternative approach and further interpretation for LCA assessment.



		Fossil Fuel Consumption	Global Warming	Acidification	Human Health Criteria – Respiratory	Eutrophication	Ozone Layer Depletion	Smog
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)	(moles of H+eq)	(kg PM10eq)	(kg Neq)	(kg CFC-11eq)	(kg O3eq)
Product Stage	Manufacturing	20604829.03	1960866.6	14757.92161	5227.31595	1082.437165	0.01205488	231686.1
	Transport	929403.1266	57204.361	346.8375733	9.80871563	24.31805862	2.326E-06	12278.26
	Total	21534232.16	2018070.9	15104.75918	5237.12467	1106.755224	0.0120572	243964.3

		Fossil Fuel Consumption	Global Warming	Acidification	Human Health Criteria – Respiratory	Eutrophication	Ozone Layer Depletion	Smog
Life Cycle Stage	Process Module	(MJ)	(kg CO2eq)	(moles of H+eq)	(kg PM10eq)	(kg Neq)	(kg CFC-11eq)	(kg O3eq)
Construction Process	Construction-installation Process	1222515.235	115745.5939	909.3548148	222.931855	51.57106642	0.0005337	24267.28
	Transport	1413781.748	107320.2118	503.0873934	15.5140787	36.25034599	4.28E-06	17789.77
	Total	2636296.983	223065.8057	1412.442208	238.445934	87.8214124	0.0005379	42057.05

Figure 33 - Henry Angus environmental impact

Annex A - Interpretation of Assessment Results

Benchmark Development

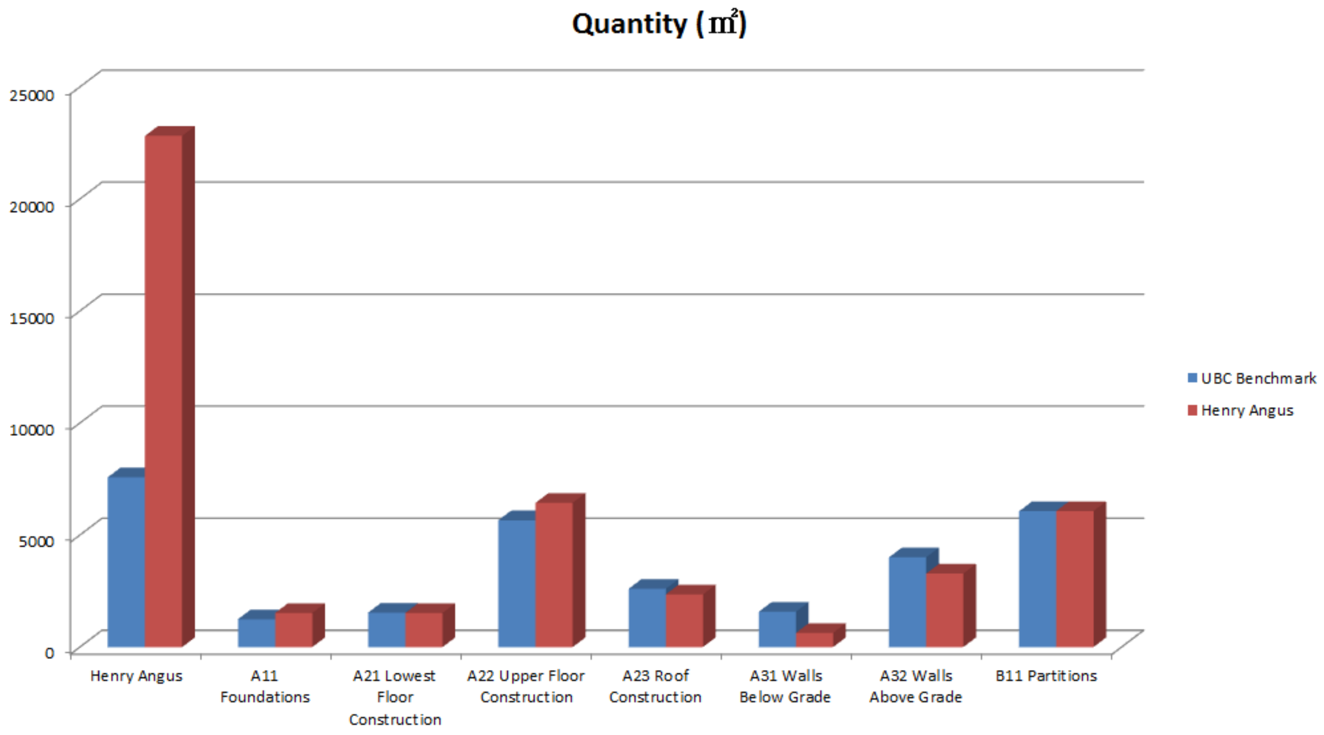
The benchmark is described to be a tool being developed to provide organizations a methodology for collecting and analysing building environmental impacts data, with the purpose of evaluating and comparison impacts with other entities in LCA. The benchmark allows the clients or stakeholders to make comparable sense of the building environmental impact performance and utilized LCA-based information to figure out the difference with other “neighbours” for further LCA study or improvement. Considering the benchmark of Henry Angus Buildings in other buildings on campus, it is noticed that the building perform more environmental friendly than most of others. That is the reason that it got the reward of LLED Silver.

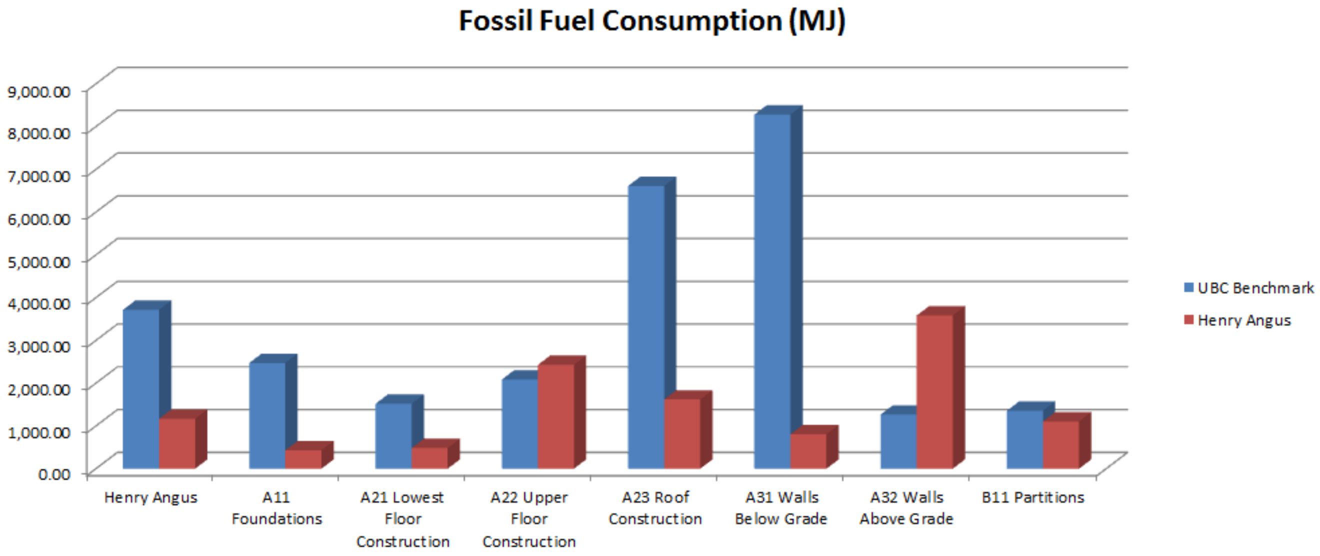
The common goal conducts strategy and development of LCA assessment, the scope regulates the application boundary and process. The model development is the outcome of iterative assessment process, identifying the invalidity and inaccuracy in the model before proceeding declaration, also providing clients with alternative approach to reassess the project.

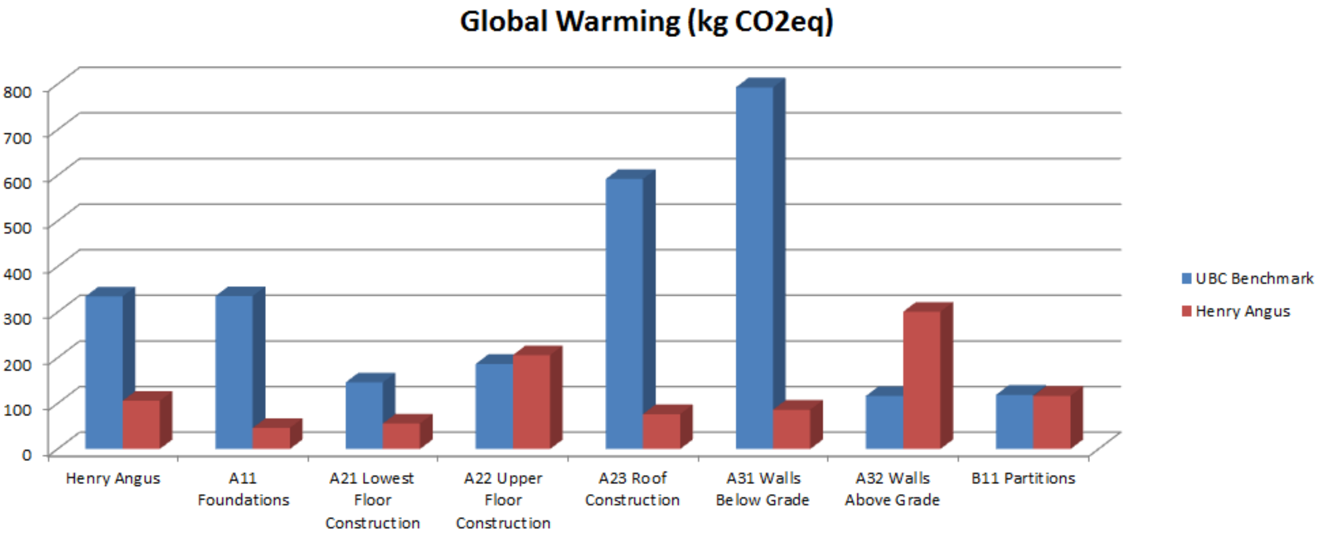
The functional equivalent is a representation of the required technical characteristics and functionalities of the building. It explains which the characteristics of the building are rationalised into description object of assessment. The functional equivalence of the benchmark provides the decision maker with clear LCA-based results of the building that indicates whether it is in harmony with the current policy or standards related to green buildings or sustainability, or to build new, or refurbish an existing building, the evaluation of the design options, locations, etc.

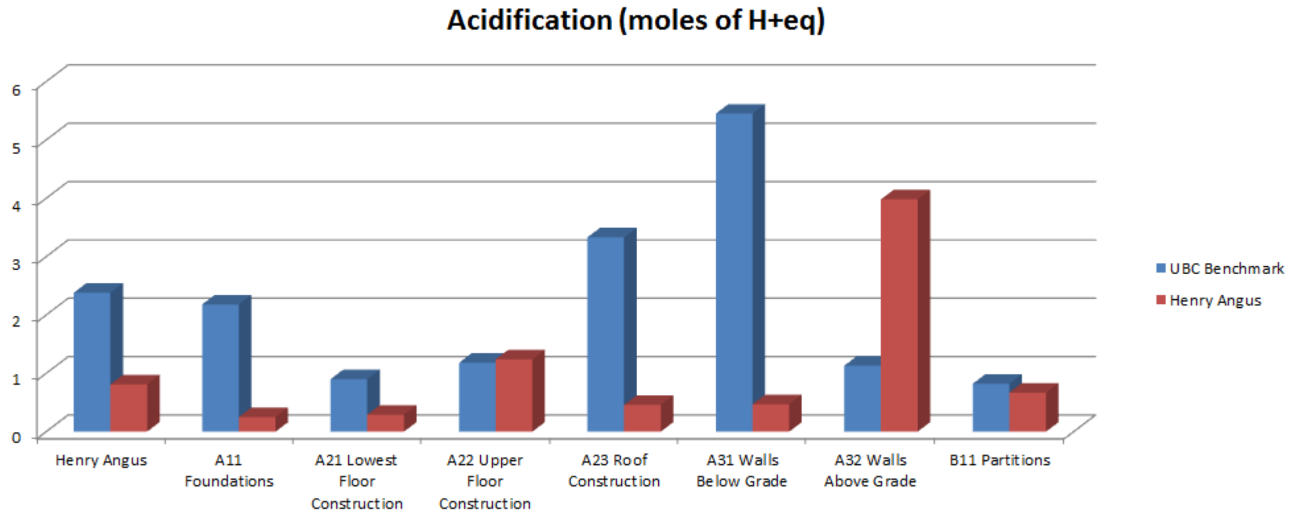
UBC Academic Benchmark Development

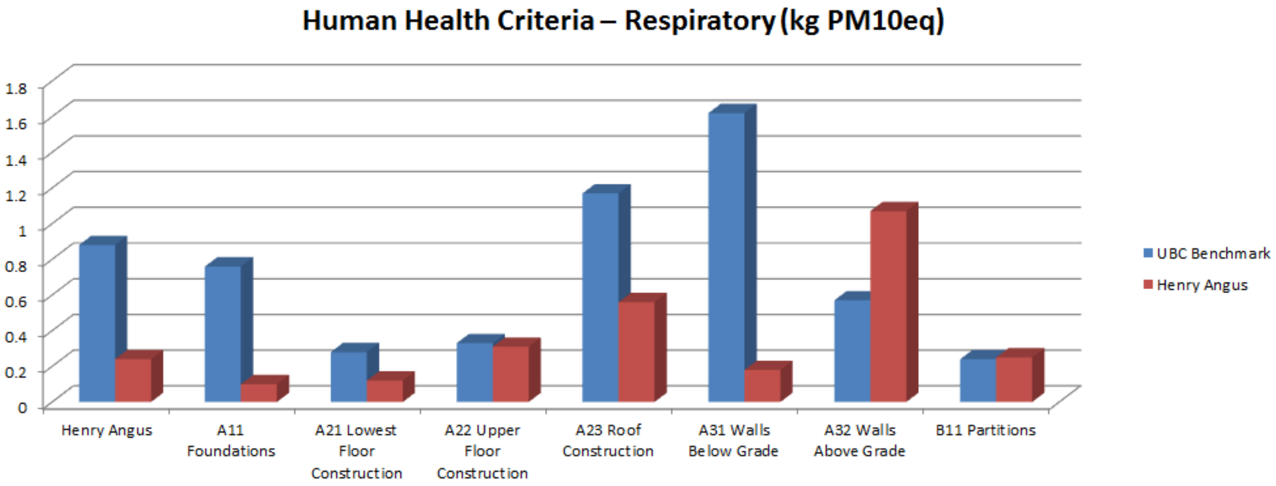
The study compared result of Henry Angus Building with other buildings completed the life cycle assessment on campus in terms of quantity and all impact indicators as below. The red column is representation of Henry Angus Building performance. From the whole life cycle stage perspective, it is just approximately equals to one third of the benchmark, but has three times quantity than benchmark. For A11, the benchmark diagram indicates that the impact of the building is much less than UBC benchmark, except for the performance in Ozone layer depletion, it is dramatically higher than benchmark. Considering the outstanding difference, the clients need to check the LCA assessment file and the materials used in building to figure out what leads to the increase of this potential. Each of A21 comparison shows almost half of the benchmark. A22 and B11 has the similar performance as same as UBC benchmark. As we see that, the roof system of the building has a exciting performance especially in global warming 20% of the UBC benchmark. The most remarkable of the building performance is supposed to be A31 walls below grade, almost 9% of the UBC benchmark, it might result in the concrete with flyash and other sustainable material cladding instead of solid concrete. A32 wall above grade performs worst in all CIQS element, twice as much as that in UBC benchmark although its quantity is slight less than the benchmark. It is necessary for practitioners to review the material used in the exterior wall of the building that might be the trigger.

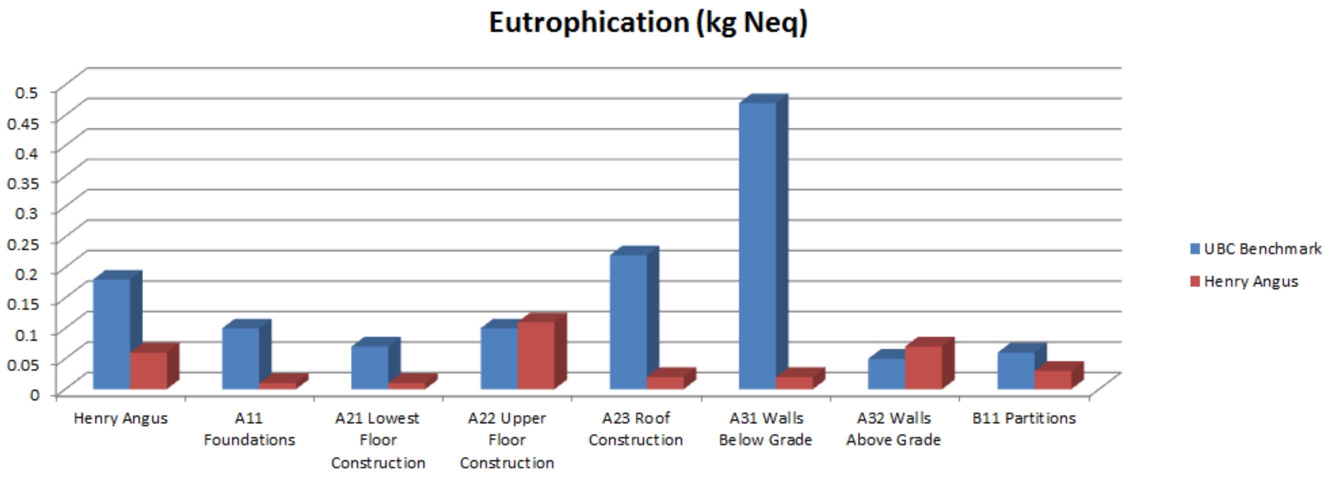


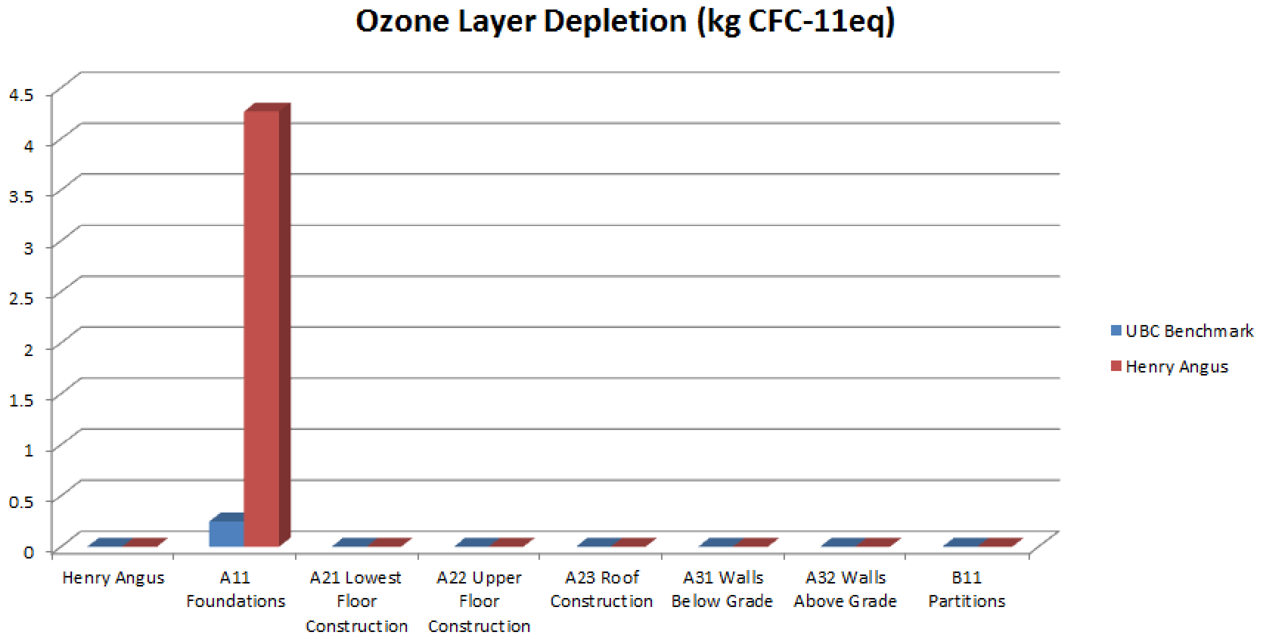

Fossil Fuel Consumption (MJ)
9,000.00
8,000.00
7,000.00
6,000.00
5,000.00
4,000.00
3,000.00
2,000.00
1,000.00
0.00
Henry Angus
A11 Foundations
A21 Lowest Floor Construction
A22 Upper Floor Construction
A23 Roof Construction
A31 Walls Below Grade
A32 Walls Above Grade
B11 Partitions
UBC Benchmark
Henry Angus


Global Warming (kg CO2eq)
800
700
600
500
400
300
200
100
0
Henry Angus
A11 Foundations
A21 Lowest Floor Construction
A22 Upper Floor Construction
A23 Roof Construction
A31 Walls Below Grade
A32 Walls Above Grade
B11 Partitions
UBC Benchmark
Henry Angus


Acidification (moles of H+eq)
6
5
4
3
2
1
0
Henry Angus
A11 Foundations
A21 Lowest Floor Construction
A22 Upper Floor Construction
A23 Roof Construction
A31 Walls Below Grade
A32 Walls Above Grade
B11 Partitions
UBC Benchmark
Henry Angus


Human Health Criteria – Respiratory (kg PM10eq)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Henry Angus
A11 Foundations
A21 Lowest Floor Construction
A22 Upper Floor Construction
A23 Roof Construction
A31 Walls Below Grade
A32 Walls Above Grade
B11 Partitions
UBC Benchmark
Henry Angus


Eutrophication (kg Neq)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Henry Angus
A11 Foundations
A21 Lowest Floor Construction
A22 Upper Floor Construction
A23 Roof Construction
A31 Walls Below Grade
A32 Walls Above Grade
B11 Partitions
UBC Benchmark
Henry Angus


Ozone Layer Depletion (kg CFC-11eq)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Henry Angus
A11 Foundations
A21 Lowest Floor Construction
A22 Upper Floor Construction
A23 Roof Construction
A31 Walls Below Grade
A32 Walls Above Grade
B11 Partitions
UBC Benchmark
Henry Angus

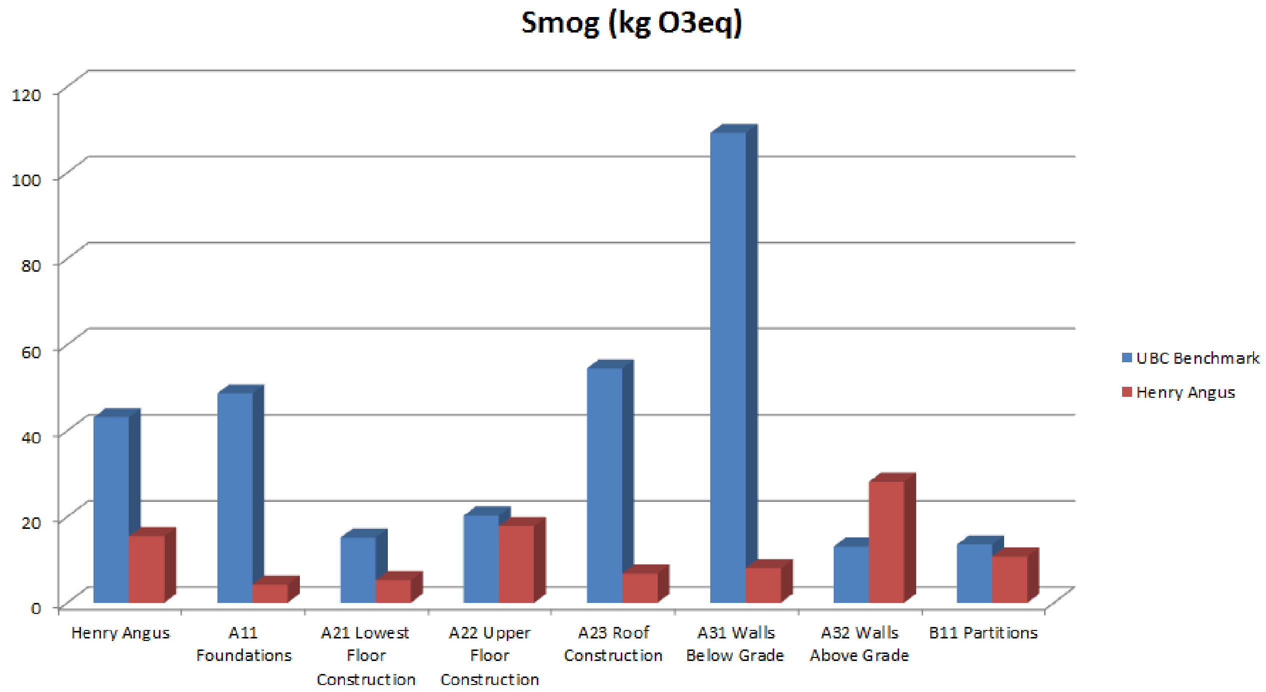


Figure 34 - Henry Angus impact benchmark

Comparing the scatter of total cost of all studies in Fig 35, it is noticed that the cost of the Henry Angus Building is second highest in all study buildings, in fact the primary of the expenditure is form the second renovation, investing almost $85M. As for the summary of the Global Warming Potential for all studies in Fig 35, it demonstrates Henry Angus Building maintained at an average level.

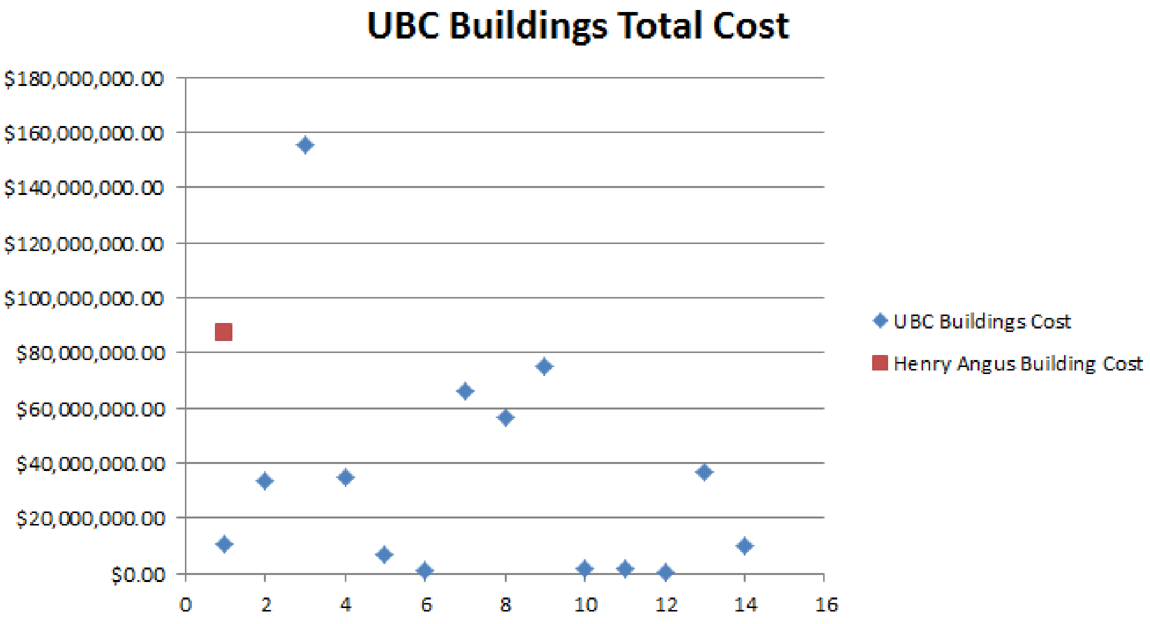


Figure 35 - Henry Angus Cost scatter plot

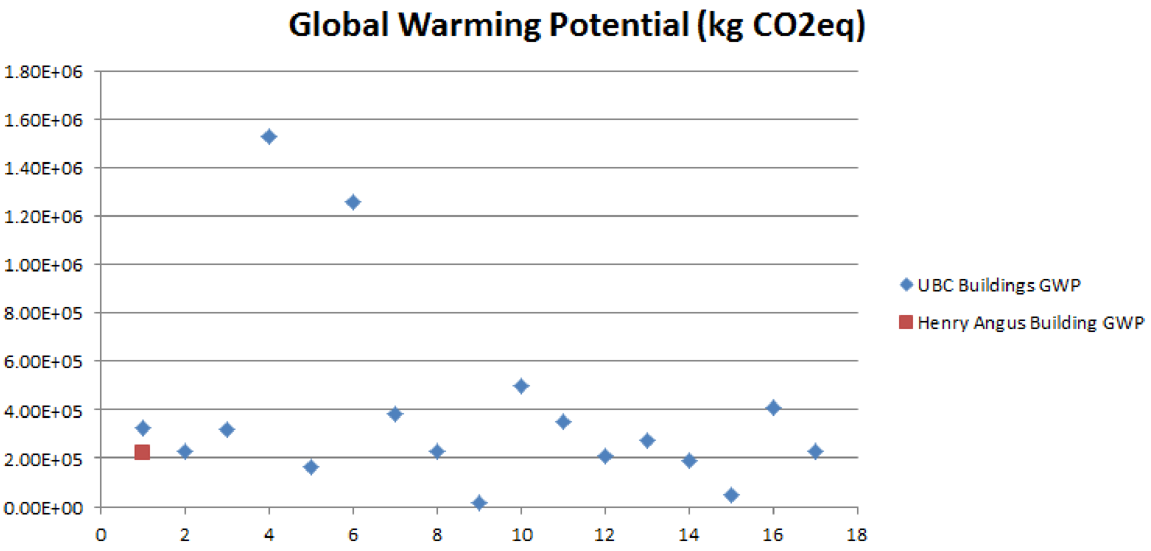


Figure 36 - Henry Angus GWP scatter plot

Annex B – Recommendations for LCA

For the existing building, the modules can conduct the practitioners' LCA-based information to forward further sustainability study. Specifically, the module approximately contains all elements' type and property of the building which might be invisible in the real practice, associated with the Athena solid database obtained from actual industry and manufactures, the modeled building can demonstrate its impacts on the environment in product and construction stage by swapping different material and redefining the geometry. Also we can estimate the building's service life according to outcome of the modules. For the project to be built, life cycle modules work as a "prophet", when estimated material are input the module, we can run the program to estimate performance of the building with required material in environment, contributing to establish a guideline or criteria before procurement and construction.

In design phase, LCA is the only way to evaluate the building performance in environment, we can establish a building LCA modules and import the elements with demand material as the process did in this study, the module will generate a profile includes the building performance in terms of each category indicator, then designer can investigate whether the estimated building performance meet their goal and scope, if not , the module provide sufficient database for users exchanging the similar functional element with less effect on environment freely. In addition, the designer is encouraging to make the benchmark form regional LCA database to compare with other buildings. In the end, designers can manage the building performance by outcome of the LCA module and improvements.

The availability and quality of data and benchmark depends on the building solid specification profiles and accuracy of the Athena database. Any insufficiency or inaccuracy will impair their availability and quality. As to Henry Angus Building, the drawings and specification are from 1960's, fuzzy drawings cause some geometry misstatement. Furthermore, twice extensive revamp introduced more uncertainties. So the up-to-date information is the key to maintain it to be validity. As for the Athena database, it is more creditable for product stage due to combination with real industry and manufacture database, but for the product stage, it seems to be not a solid enough database to support them that might affect its inaccuracy.

It is well known that the environmental impact result of the building generates from LCA study demonstrates seven indicators, so which one should the participants need to consider firstly is the issue in the practice. As far as I am concerned, the priority of impact categories should be Global Warming, Fossil Fuel Consumption, Smog, Human Health Criteria – Respiratory, Acidification, Eutrophication and Ozone Layer Depletion. The most effect triggered by global warming should be the "Greenhouse Effect", the increasing concentration of CO2 has threatened our ecosystem significantly, causing massive iceberg disappeared It has been proved that continuously increasing sea level would give rise to many coastal cities like Vancouver submerged. Fossil fuel consumption is related to the resources consumption, the limit resources are wasted with unwise methodology application is directly concerned with next generation. The reason out smog to the third one is due to offending haze in Beijing, it has seriously affected the citizens' daily life such as health issue and traffic safety. The quantity of the others indicators is more inappreciable.

- Outlines steps you would take to operationalize LCA data and their use in practice at UBC.
    - Establish the goal and scope of the LCA study based on the project requirement and regional policy and standard.
    - Data collection from UBC database or regional database.
    - Create the modules in terms of the data from relative model information, available database and data in project documents (drawings and specifications)
    - Iterative revise module process refers to all solid documents for data accuracy and validity.
    - Run the module and evaluate the outcome of LCA meets goal and requirement, if not
    - Module improvement by swapping material and redefining geometry that might be inaccurate in the building.
    - Manage the project from product stage to construction stage (assumed to apply module A) with LCA study as guideline.

Annex C – Author Reflection

I experienced my first LCA study in the course "Advanced BIM", one of my topics is related to embodied energy. I employed the Athena EcoCalculator for exploring the embodied energy for the project "Engineering Student Center" to be built. In the end, I came up with some suggestions for diminishing the building effect in environmental by exchanging the materials of the component in the EcoCalcualtor based on assumption and specifications.

What I learned from the course is a complete set of LCA methodology, and how to apply it into the real practice; especially the improved model development and benchmark comparison are profound for the further study.

I have some suggestions for the LCA study. For the Henry Angus Building analysis, some of the material or element list in the EI model can be traced 1960's, but the model assumed them to be produced in present, in fact, the production of these elements would result in much more serious effect on the environment due to backward technology in 1960's, the issue is that how can we develop an ancillary methodology assesses this kind of inaccuracy to support current LCA methodology.

	Graduate Attribute		Select the content code most appropriate for each attribute from the dropdown menue	Comments on which of the CEAB graduate attributes you believe you had to demonstrate during your final project experience.
	Name	Description		
1	Knowledge Base	Demonstrated competence in university level mathematics, natural sciences, engineering fundamentals, and specialized engineering knowledge appropriate to the program.	ID = introduced & developed	I leaned the explicit methodology and the process how it works in the real practice
2	Problem Analysis	An ability to use appropriate knowledge and skills to identify, formulate, analyze, and solve complex engineering problems in order to reach substantiated conclusions.	IA = introduced & applied	I leaned how to analyze the EL model and make improvements by exchaning som specific. The resuts turns out that avaliable imprvments can reduce the building environmental performance.

3 Investigation	An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.	ID = introduced & developed	In the CIQS sort, I compare the material descrided in IE inouts and Known measure inputs, and investigate the inaacurancy of some materials.
4 Design	An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.	D = developed	Foe this part, I got involve few design process.
5 Use fo Engineering Tools	An ability to create, select, apply, adapt, and extend appropriate techniques, resources, and modern engineering tools to a range of engineering activities, from simple to complex, with an understanding of the associated limitations.	DA = developed & applied	EI model is quite well tool for engineer to estimate the building impact. I learn how to use LCA tool and database for evaluating the building performance
6 Individual and Team Work	An ability to work effectively as a member and leader in teams, preferably in a multi-disciplinary setting.	IA = introduced & applied	I participated effectively in the team discussion and come up with some good ideas.

7 Communication	An ability to communicate complex engineering concepts within the profession and with society at large. Such ability includes reading, writing, speaking and listening, and the ability to comprehend and write effective reports and design documentation, and to give and effectively respond to clear instructions.	ID = introduced & developed	I read a lot of excellent papers related to the LCA and get deeper understand about LCA
8 Professionalism	An understanding of the roles and responsibilities of the professional engineer in society, especially the primary role of protection of the public and the public interest.	D = developed	the professional can help the fresh evaluate their data accuracy or not.
9 Impact of Engineering on Society and the Environment	An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.	A = applied	the LCA study contributes to the huamn health and make the building more environmental friendlly.

Ethics and Equity	An ability to apply professional ethics, accountability, and equity.	ID = introduced & developed	the practitioners should review and compare the inaccuracy beteeen database and known measure input
Economics and Project Management	An ability to appropriately incorporate economics and business practices including project, risk, and change management into the practice of engineering and to understand their limitations.	ID = introduced & developed	the practioners can controlelemtnt and material of the building energy consumption in product sand construction stage by manage the LCA result in model
Life-long Learning	An ability to identify and to address their own educational needs in a changing world in ways sufficient to maintain their competence and to allow them to contribute to the advancement of knowledge.	ID = introduced & developed	The LCA methodology and associated tools have a profound effect in the further sustainable building research.

Reference

1. EeBGuide Project – Operational Guidance for Life Cycle Assessment Studies of the Energy Efficient Buildings Initiative, posted October 18,2012

2. Life Cycle Assessment Handbook: A Guide for Environmentally Sustainable Products. Mary Ann Curran.

3. “Treatment of Uncertainties in Life Cycle Assessment” Jack W. Baker Michael D. Lepech Stanford University, Stanford, USA

4. Hybrid Framework for Managing Uncertainty in Life Cycle Inventories, Eric D. Williams, Christopher L. Weber, and Troy R. Hawkins

5. Canadian Standards Association. (2006). CSA Standard CAN/CSA-ISO 14040:06. International

6. Organization for Standardization (ISO).

7. Athena Sustainable Materials Institute, “Life Cycle inventory of ICI roofing systems: Onsite construction effects”, Ottawa 2001

Annex D – Impact Estimator Input and Assumption

Assembly Group	Assembly Type	Assembly Number	Assembly Name	Input Fields	Known Measures	EIE Inputs
A11 Foundations 1522 m^2						
	1.2 Footings in Classroom Block					
		1.2.1	Footing_TypeA_ClassroomBlock	Length (ft)	5.83	11.66
				Width (ft)	5.17	5.17
				Thickness (in)	24	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	6	6
		1.2.2	Footing_TypeB_ClassroomBlock	Length (ft)	5.5	11
				Width (ft)	4.83	4.83
				Thickness (in)	24	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	6	6
		1.2.3	Footing_TypeC_ClassroomBlock	Length (ft)	3.5	3.5
				Width (ft)	3.5	3.5
				Thickness (in)	18	18
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5

		1.2.4	Footing_3'0"_S2&S4_S11&S13_ClassroomBlock	Length (ft)	229	229
				Width (ft)	3	3
				Thickness (in)	18	18
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.2.5	Footing_2'6"_S1_ClassroomBlock	Length (ft)	80	80
				Width (ft)	2.5	2.5
				Thickness (in)	15	15
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.2.6	Footing_TypeD_ClassroomBlock	Length (ft)	3	3
				Width (ft)	10.33	10.33
				Thickness (in)	15	15
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.2.7	Footing_TypeE_ClassroomBlock	Length (ft)	11	18.33
				Width (ft)	3.75	3.75
				Thickness (in)	20	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.2.8	Footing_TypeF_ClassroomBlock	Length (ft)	20	33.33
				Width (ft)	4	4
				Thickness (in)	20	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.2.9	Footing_TypeG_ClassroomBlock	Length (ft)	12	12
				Width (ft)	3	3
				Thickness (in)	15	15
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.2.10	Footing_2'0"_S3&S5_ClassroomBlock	Length (ft)	125	125
				Width (ft)	2	2
				Thickness (in)	18	18
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.2.11	Footing_2'0"_S6-10_ClassroomBlock	Length (ft)	212	212
				Width (ft)	2	2
				Thickness (in)	15	15
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5

		1.2.12	Footing_1'6"_S12_ClassroomBlock	Length (ft)	33	33
				Width (ft)	1.5	1.5
				Thickness (in)	12	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	4
		1.2.13	Footing_TypeH_ClassroomBlock	Length (ft)	2.5	2.5
				Width (ft)	2.5	2.5
				Thickness (in)	12	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	4
		1.2.14	Footing_RetainingWall_8"_S15_ClassroomBlock_1	Length (ft)	27.5	27.5
				Width (ft)	2.5	2.5
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	4
		1.2.15	Footing_RetainingWall_10"_S16_ClassroomBlock_1	Length (ft)	27.33	27.33
				Width (ft)	4	4
				Thickness (in)	10	10
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.2.16	Footing_RetainingWall_8"_S17_ClassroomBlock_1	Length (ft)	28.17	28.17
				Width (ft)	2.17	2.17
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	4

	1.3 Footings in Office Block	1.3.1	Footing_2'6"_S1_S7-10_Office	Length (ft)	41	41
				Width (ft)	2.5	2.5
				Thickness (in)	15	15
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.3.2	Footing_2'6"_S2_Office	Length (ft)	102	153
				Width (ft)	2.5	2.5
				Thickness (in)	18	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.3.3	Footing_2'6"_S4_Office	Length (ft)	74	222
				Width (ft)	2.5	2.5
				Thickness (in)	36	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	4
		1.3.4	Footing_2'6"_S5_Office	Length (ft)	41	123
				Width (ft)	2.5	2.5
				Thickness (in)	36	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.3.5	Footing_3'6"_S6_Office	Length (ft)	211	633
				Width (ft)	3.5	3.5
				Thickness (in)	36	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.3.6	Footing_4'0"_S14_Office	Length (ft)	79	79
				Width (ft)	4	4
				Thickness (in)	10	10
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	4
		1.3.7	Footing_2'_S2_Office	Length (ft)	20	30
				Width (ft)	2	2
				Thickness (in)	18	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.3.8	Footing_2'6"_Curb_Office	Length (ft)	179	179
				Width (ft)	2.5	2.5
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5

	1.4 Retaining Walls	1.4.1	Footing_Retaining Wall_8"_S15_ClassroomBlock_2	Length (ft)	27.5	27.5
				Height (ft)	6.17	6.17
				Components	Cast in place	Cast in place
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
		1.4.2	Footing_Retaining Wall_10"_S16_ClassroomBlock_2	Length (ft)	27.33	27.33
				Height (ft)	8.83	8.83
				Components	Cast in place	Cast in place
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
		1.4.3	Footing_Retaining Wall_8"_S17_ClassroomBlock_2	Length (ft)	28.17	28.17
				Height (ft)	12.75	12.75
				Components	Cast in place	Cast in place
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
		1.4.4	RetainingWall_8"_OfficeBlock	Length (ft)	114	114
				Height (ft)	11.33	11.33
				Components	Cast in place	Cast in place
				Thickness (inches)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5

A21 Lowest Floor Construction 1522 ㎡						
	1.1 Concrete Slab-on-Grade					
		1.1.1	SOG_ClassroomBlock_5"	Length (ft)	139.28	87.05
				Width (ft)	139.28	139.28
				Thickness (in)	5	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
		1.1.2	SOG_OfficeBlock_5"	Length (ft)	82.49	51.56
				Width (ft)	82.49	82.49
				Thickness (in)	5	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average

A22 Upper Floor Construction 6437 ㎡	**2.1 Suspended Slab**					
		2.1.1	Floor_SuspendedSlab_6"	Width (ft)	55.80322571	155.7
				Span (ft)	55.80322571	20
				Live Load (psf)	60 & 100	75
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
		2.1.2	Floor_SuspendedSlab_7"	Width (ft)	87.7667363	385.15
				Span (ft)	87.7667363	20
				Live Load (psf)	60 & 100	75
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
		2.1.3	Floor_SuspendedSlab_4.5"	Width (ft)	129.0465032	832.65
				Span (ft)	129.05	20
				Live Load (psf)	60 & 100	75
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
		2.1.4	Floor_SuspendedSlab_4"	Width (ft)	47.02127178	110.55
				Span (ft)	47.02127178	20
				Live Load (psf)	60 & 100	75
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
		2.1.5	Floor_SuspendedSlab_8"	Width (ft)	184.2498304	1697.4
				Span (ft)	184.2498304	20
				Live Load (psf)	60 & 100	75
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
		2.1.6	Floor_SuspendedSlab_7"_Floors3to8	Width (ft)	21.3541565	22.8
				Span (ft)	21.3541565	20
				Live Load (psf)	60 & 100	75
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
		2.1.7	Floor_SuspendedSlab_5"	Width (ft)	72.11102551	260
				Span (ft)	72.11102551	20
				Live Load (psf)	60 & 100	75
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
	2.2 Precast					
		2.2.1	Floor_Precast_Detail A	Number of Bays	276	276
				Bay size (ft)	3.33	3.33
				Span (ft)	29.1	29.1
				Live Load (psf)	60 & 100	75
				Concrete Topping (in)	2.5	With

2.3 XBM	2.3.2	XBM_1"_lino_tile_topping	XBM	Lino	Vinyl Cladding
			Area (sf)	76341	76341
5.1 Columns with Beams	5.1.1	Columns_Concrete_Beams_Concrete_Basement_ClassroomBlock	Number of Columns	50	50
			Number of Beams	24	24
			Floor to Floor Height (ft)	10.83	10.83
			Bay Sizes (ft)	47.5	35
			Supported Span (ft)	13.33	18.1
			Live Load (psf)	-	100
			Supported Area (sf)	15188	-
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
	5.1.2	Columns_Concrete_Beams_Concrete_GroundFloor_ClassroomBlock	Number of Columns	58	58
			Number of Beams	40	40
			Floor to Floor Height (ft)	13.5	13.5
			Bay Sizes (ft)	13.75, 27.5 & 12	23.8
			Supported Span (ft)	13.17 & 56	21.2
			Live Load (psf)	-	100
			Supported Area (sf)	15188	-
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
	5.1.3	Columns_Concrete_Beams_Concrete_Basement_OfficeBlock	Number of Columns	44	44
			Number of Beams	19	19
			Floor to Floor Height (ft)	10.83	10.83
			Bay Sizes (ft)	16.75 & 19.5	17.67
			Supported Span (ft)	20 & 10	15.83
			Live Load (psf)	-	100
			Supported Area (sf)	5316	-
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete

5.2 Columns without Beams	5.2.1	Columns_Concrete_Beams_N/A_SecondtoFourthFloor_ClassroomBlock	Number of Columns	150	150
			Number of Beams	0	0
			Floor to Floor Height (ft)	11.75	11.75
			Bay Sizes (ft)	29.08	29.08
			Supported Span (ft)	13.33	13.33
			Live Load (psf)	-	100
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
	5.2.2	Columns_Concrete_Beams_N/A_Penthouse_ClassroomBlock	Number of Columns	20	20
			Number of Beams	0	0
			Floor to Floor Height (ft)	10.58	10.58
			Bay Sizes (ft)	12.33	12.33
			Supported Span (ft)	13.33	13.33
			Live Load (psf)	-	100
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
	5.2.3	Columns_Concrete_Beams_N/A_GroundFloor_OfficeBlock	Number of Columns	44	44
			Number of Beams	0	0
			Floor to Floor Height (ft)	12.5	12.5
			Bay Sizes (ft)	17.67	17.67
			Supported Span (ft)	10	10
			Live Load (psf)	-	100
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
	5.2.4	Columns_Concrete_Beams_N/A_SecondFloor_OfficeBlock	Number of Columns	44	44
			Number of Beams	0	0
			Floor to Floor Height (ft)	8.75	8.75
			Bay Sizes (ft)	16.75 & 19.5	17.67
			Supported Span (ft)	10	10
			Live Load (psf)	-	100
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete
	5.2.5	Columns_Concrete_Beams_N/A_Floors3to8_OfficeBlock	Number of Columns	264	264
			Number of Beams	0	0
			Floor to Floor Height (ft)	8.75	8.75
			Bay Sizes (ft)	16.75 & 19.5	17.67
			Supported Span (ft)	10	10
			Live Load (psf)	-	100
			Column Type	Concrete	Concrete
			Beam Type	Concrete	Concrete

6.1 Stairs	6.1.1	Stairs_Southeast_Basement_L1_1	Length (ft)	25.71	15
			Width (ft)	9	9
			Thickness (in)	7	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.2	Stairs_Southeast_L1_L2_2	Length (ft)	6.86	3.9
			Width (ft)	13	13
			Thickness (in)	7	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.3	Stairs_Southeast_L1_L2_1	Length (ft)	12	7
			Width (ft)	9	9
			Thickness (in)	7	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.4	Stairs_Southeast_L1_L2_3	Length (ft)	9	3
			Width (ft)	9	9
			Thickness (in)	4	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.5	Stairs_Southeast_L1_L2_4	Length (ft)	48	12
			Width (ft)	9	9
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4

	6.1.6	Stairs_Southeast_L2_L3_1	Length (ft)	12	4
			Width (ft)	9	9
			Thickness (in)	4	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.7	Stairs_Southeast_L2_L4	Length (ft)	60	20
			Width (ft)	9	9
			Thickness (in)	4	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.8	Stairs_Southeast_L4_L6	Length (ft)	42	21
			Width (ft)	5	5
			Thickness (in)	6	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.9	Stairs_Southeast_L6_ConferenceRoo	Length (ft)	99	33
			Width (ft)	5	5
			Thickness (in)	4	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.10	Stairs_Southwest_Office_Basement_	Length (ft)	136	34
			Width (ft)	3.67	3.67
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4

	6.1.11	Stairs_Southwest_Office_L3_Roof	Length (ft)	224	56
			Width (ft)	3.67	3.67
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.12	Stairs_Southwest_Office_Penthouse	Length (ft)	16	4
			Width (ft)	3.67	3.67
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.13	Stairs_North_Class_Basement_L2_width=9'	Length (ft)	96	9
			Width (ft)	9	9
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.14	Stairs_North_Class_L1_width=17'5"	Length (ft)	16	4
			Width (ft)	17.42	17.42
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.15	Stairs_North_Class_L2_L4_width=9'	Length (ft)	112	28
			Width (ft)	9	9
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	3	4
	6.1.16	Stairs_North_Class_L4_Roof_width=9'	Length (ft)	36	9
			Width (ft)	9	9
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	5	5
	6.1.17	Stairs_North_Class_L4_Roof_width=4'	Length (ft)	16	4
			Width (ft)	4	4
			Thickness (in)	3	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	5	5

	4.1 Precast	4.1.1		Number of Bays	96	96
A23 Roof Construction 2351 ㎡			Roof_Precast_ClassroomBlock_2.5"	Bay Size (ft)	3.33	3.33
				Span (ft)	-	17.97
			Area = 8626 sf	Live Load (psf)	27	45
				Concrete Topping	-	Yes
				Type	Built-up	Built-up
			Envelope	Category	Insulation	Insulation
				Material	Rigid Insulation	Polystyrene Extruded, Orgainic Felt
				Thickness (in)	1	1
	4.2 Suspended Slab	4.2.1		Roof Width (ft)	245.84	245.84
			Roof_SuspendedSlab_Penthouse_ClassroomBlock_4"	Span (ft)	13.33	13.33
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
			Area = 3277 sf	Live Load (psf)	27	45
				Type	Built-up	Built-up inverted
			Envelope	Category	Insulation	Insulation
				Material	Rigid Insulation	Polystyrene
				Thickness (in)	1	1
		4.2.2	Roof_SuspendedSla	Roof Width (ft)	598.70	598.7
			Area = 5987 sf	Span (ft)	10	10
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Live Load (psf)	27	45
				Type	Built-up	Built-up inverted
			Envelope	Category	Insulation	Insulation
				Material	Rigid Insulation	Polystyrene Extruded, Orgainic Felt
				Thickness (in)	1	1

		4.2.3		Roof Width (ft)	588.70	588.7
			Roof_SuspendedSlab_OfficeBlock_7"	Span (ft)	10	10
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
			Area = 5887 sf	Live Load (psf)	27	45
				Type	Built-up	Built-up inverted
			Envelope	Category	Insulation	Insulation
				Material	Rigid Insulation	Polystyrene Extruded, Orgainic Felt
				Thickness (in)	1	1
		4.2.4		Roof Width (ft)	140.10	140.1
			Roof_SuspendedSlab_Penthouse_OfficeBlock_3.5"	Span (ft)	10	10
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
			Area = 1401 sf	Live Load (psf)	27	45
				Type	Built-up	Built-up inverted
			Envelope	Category	Insulation	Insulation
				Material	Rigid Insulation	Polystyrene Extruded, Orgainic Felt
				Thickness (in)	1	1
		4.2.5		Length (ft)	516	129
			Roof_SuspendedSlab_Penthouse_OfficeBlock_2'6"	Height (ft)	2.5	2.5
				Thickness (in)	3	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
			Area = 129 sf	Rebar #	3, 4 & 5	5
				Type	Concrete Block	Concrete Block

A31 Walls Below Grade 635 m²						
	3.1 Classroom Block					
		3.1.1	Wall_Concrete_Footing_8"_S14_ClassroomBlock	Length (ft)	24	24
				Height (ft)	8.5	8.5
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5
		3.1.6	Walls_Cast-in-place_Basement_ClassroomBlock_9"_	Length (ft)	662	496.5
				Height (ft)	10.83	10.83
				Thickness (in)	9	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
		3.2.2	Walls_Cast-in-place_Basement_OfficeBlock_9"_2	Length (ft)	136	102
				Height (ft)	10.83	10.83
				Thickness (in)	9	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
		3.2.3	Walls_Cast-in-place_Basement_OfficeBlock_10"	Length (ft)	17	14.17
				Height (ft)	10.83	10.83
				Thickness (in)	10	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior

A32 Walls Above Grade 3280 ㎡	**3.1 Classroom Block**	3.1.8	Walls_Cast-in-place_GroundFloor_ClassroomBlock_11"	Length (ft)	92	84.33
				Height (ft)	13.5	13.5
				Thickness (in)	11	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
			Window Opening	Number of Windows	2	2
				Total Window Area (ft2)	43	43
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard
		3.1.9	Walls_Cast-in-place_GroundFloor_ClassroomBlock_9"	Length (ft)	32	29.33
				Height (ft)	13.5	13.5
				Thickness (in)	11	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
			Window Opening	Number of Windows	2	2
				Total Window Area (ft2)	60	60
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard

		3.1.10	Walls_Cast-in-place_GroundFloor_ClassroomBlock_8"	Length (ft)	1	1
				Height (ft)	13.5	13.5
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5
		3.1.11	Walls_Cast-in-place_GroundFloor_ClassroomBlock_12"	Length (ft)	11	11
				Height (ft)	13.5	13.5
				Thickness (in)	12	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5
		3.1.13	Walls_Cast-in-place_GroundFloor_ClassroomBlock_2'	Length (ft)	11	22
				Height (ft)	13.5	13.5
				Thickness (in)	24	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
			Window Opening	Number of Windows	2	2
				Total Window Area (ft2)	63	63
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard
			Door Opening	Number of Doors	2	2
				Door Type	Glazing	Aluminum Ext. Door 80% Glazing

		3.1.14	Walls_Cast-in-place_GroundFloor_ClassroomBlock_1'1"	Length (ft)	69	74.75
				Height (ft)	13.5	13.5
				Thickness (in)	13	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
			Window Opening	Number of Windows	19	19
				Total Window Area (ft2)	492	492
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard
		3.1.16	Walls_Cast-in-place_GroundFloor_ClassroomBlock_7"_2	Length (ft)	95.6	55.77
				Height (ft)	13.5	13.5
				Thickness (in)	7	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5
		3.1.18	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_1'10"	Length (ft)	35	64.17
				Height (ft)	11.75	11.75
				Thickness (in)	22	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
			Window Opening	Number of Windows	4	4
				Total Window Area (ft2)	121	121
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard

		3.1.19	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_1'8"	Length (ft)	84	140
				Height (ft)	11.75	11.75
				Thickness (in)	20	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
			Window Opening	Number of Windows	10	10
				Total Window Area (ft2)	300	300
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard
		3.1.20	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_1'	Length (ft)	50	50
				Height (ft)	11.75	11.75
				Thickness (in)	12	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
		3.1.21	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_6"	Length (ft)	67	33.5
				Height (ft)	11.75	11.75
				Thickness (in)	6	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
			Window Opening	Number of Windows	4	4
				Total Window Area (ft2)	86	86
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard

		3.1.22	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_9"	Length (ft)	143	107.25
				Height (ft)	11.75	11.75
				Thickness (in)	9	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5
		3.1.23	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_11"	Length (ft)	2	1.83
				Height (ft)	11.75	11.75
				Thickness (in)	11	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Fibreglass Batt	Fibreglass Batt
				Thickness (in)	2	2
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5
		3.1.26	Walls_Cast-in-place_Ledge_ClassroomBlock_Roof_6"	Length (ft)	503	251.5
				Height (ft)	1.83	1.83
				Thickness (in)	6	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	3	5
				Wall Type	Exterior	Exterior
		3.1.29	Walls_Suspended_Cast-in-place_ClassroomBlock_11"	Length (ft)	60.89	55.82
				Height (ft)	60.89	60.89
				Thickness (in)	11	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Exterior	Exterior
		3.1.30	Suspended_Cast-in-place_ClassroomBlock_6"_rebar#4	Length (ft)	61.86	30.93
				Height (ft)	61.86	61.86
				Thickness (in)	6	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior

		3.1.31	Suspended_Cast-in-place_ClassroomBlock_6"_rebar#5	Length (ft)	10.39	5.2
				Height (ft)	10.39	10.39
				Thickness (in)	6	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Exterior	Exterior
		3.1.32	Suspended_Cast-in-place_ClassroomBlock_1'4"	Length (ft)	12.49	16.65
				Height (ft)	12.49	12.49
				Thickness (in)	16	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Exterior	Exterior
	3.2 Office Block	3.2.12	Walls_Cast-in-place_GroundFloor_OfficeBlock_5.5"	Length (ft)	136	62.33
				Height (ft)	12.5	12.5
				Thickness (in)	5.5	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Styrofoam	Expanded Polystrene
				Thickness (in)	1	1
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5
		3.2.13	Walls_Cast-in-place_GroundFloor_OfficeBlock_7.75"	Length (ft)	207	62.33
				Height (ft)	0.75	0.75
				Thickness (in)	7.75	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
		3.2.14	Walls_Cast-in-place_GroundFloor_OfficeBlock_5"	Length (ft)	32	13.33
				Height (ft)	0.75	0.75
				Thickness (in)	5	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
		3.2.18	Walls_Cast-in-place_TypicalFloor_OfficeBlock_5.5"	Length (ft)	56	25.67
				Height (ft)	8.75	8.75
				Thickness (in)	5.5	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
			Envelope	Category	Insulation	Insulation
				Material	Styrofoam	Expanded Polystrene
				Thickness (in)	1	1
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5

		3.2.23	Walls_Cast-in-place_Ledge_OfficeBlock_Penthouse_6"	Length (ft)	159	79.5
				Height (ft)	12.083	12.083
				Thickness (in)	6	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
		3.2.24	Walls_Cast-in-place_Ledge_OfficeBlock_Penthouse_9"	Length (ft)	50	37.5
				Height (ft)	11.083	11.083
				Thickness (in)	9	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
		3.2.25	Walls_Cast-in-place_Curb_OfficeBlock_8'	Length (ft)	333	333
				Height (ft)	11	11
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior

3.3 Theatre					
	3.3.1	Walls_Cast-in-place_Theatre_11"	Length (ft)	82	75.17
			Height (ft)	21.583	21.583
			Thickness (in)	11	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Exterior	Exterior
		Envelope	Category	Insulation	Insulation
			Material	Insulation Batt	Fibreglass Batt
			Thickness (in)	2	2
		Envelope	Category	Cladding	Insulation
			Material	lywood Sheet Vin	Vinyl Siding
			Thickness (in)	0.5	-
	3.3.2	Walls_Cast-in-place_Theatre_12"	Length (ft)	85	85
			Height (ft)	21.583	21.583
			Thickness (in)	12	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Exterior	Exterior
		Envelope	Category	Insulation	Insulation
			Material	Insulation Batt	Fibreglass Batt
			Thickness (in)	2	2
		Envelope	Category	Cladding	Insulation
			Material	lywood Sheet Vin	Vinyl Siding
			Thickness (in)	0.5	-
	3.3.3	Walls_Cast-in-place_Theatre_7"	Length (ft)	10	5.83
			Height (ft)	21.583	21.583
			Thickness (in)	7	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Exterior	Exterior
		Envelope	Category	Insulation	Insulation
			Material	Insulation Batt	Fibreglass Batt
			Thickness (in)	2	2

3.4 Mullions & XBM					
	3.4.1		Length (ft)	525	153.125
		Walls_Mullions_Pr	Height (ft)	11.75	11.75
		ecastConcrete_Typ	Thickness (in)	7	12
		icalFloor_Classroo	Concrete Strength (psi)	-	3000
		mBlock_7"	Concrete Flyash %	-	Average
			Rebar #	4	5
		Window Opening	Wall Type	Exterior	Exterior
			Number of Windows	156	156
		*Walls_Mullions_P	Total Window Area (ft2)	1404	1404
		recastConcrete_Ty	Fixed/Operable	Fixed	Fixed
			Frame Type	Metal	Aluminum
		Window Opening	Glazing Type	Standard	Standard
			Number of Windows	156	156
		*Walls_Mullions_P	Total Window Area (ft2)	1248	1248
		recastConcrete_Ty	Fixed/Operable	Operable	Operable
		picalFloor_Classro	Frame Type	Metal	Aluminum
		omBlock_7"_2	Glazing Type	Standard	Standard
	3.4.2		Length (ft)	429	429
		Walls_Mullions_Pr	Height (ft)	11.75	11.75
		ecastConcrete_Typ	Thickness (in)	24	12
		icalFloor_Classroo	Concrete Strength (psi)	-	3000
		mBlock_2'	Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Exterior	Exterior
		Window Opening	Number of Windows	117	117
		*Walls_Mullions_P	Total Window Area (ft2)	1053	1053
		recastConcrete_Ty	Fixed/Operable	Fixed	Fixed
		picalFloor_Classro	Frame Type	Metal	Aluminum
		omBlock_2'_1	Glazing Type	Standard	Standard
		Window Opening	Number of Windows	117	117
		*Walls_Mullions_P	Total Window Area (ft2)	819	819
		recastConcrete_Ty	Fixed/Operable	Operable	Operable
		picalFloor_Classro	Frame Type	Metal	Aluminum
		omBlock_2'_2	Glazing Type	Standard	Standard

		3.4.3	Walls_Mullions_PrecastConcrete_TypicalFloor_OfficeBlock_7"	Length (ft)	1428	416.5
				Height (ft)	8.75	8.75
				Thickness (in)	7	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
			Window Opening *Walls_Mullions_PrecastConcrete_TypicalFloor_OfficeBlock_7"_1	Number of Windows	210	210
				Total Window Area (ft2)	630	630
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard
			Window Opening *Walls_Mullions_PrecastConcrete_TypicalFloor_OfficeBlock_7"_2	Number of Windows	210	210
				Total Window Area (ft2)	1260	1260
				Fixed/Operable	Operable	Operable
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard
		3.4.4	Walls_XBM_Steel_Lourve_Wall_Cast-in-place_Penthouse_	Length (ft)	131.85	65.93
				Height (ft)	10.58	10.58
				Thickness (in)	6	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Exterior	Exterior
			XBM for steel cladding Envelope * Extra Cladding Material	Area (sf)	1360	3980
				Category	Cladding	Cladding
				Material	Steel Cladding	Steel Cladding
				Thickness (in)	0.0635	0.0217
				Type	Ga Galvinized Ste	26 Ga Galvinized Steel
			Door Opening	Number of Doors	1	1
				Door Type	Steel	Steel Exterior Door

B11 Partitions 6073 m²	**3.1 Classroom Block**					
		3.1.12	Walls_Cast-in-place_GroundFloor_ClassroomBlock_10"	Length (ft)	38	31.67
				Height (ft)	13.5	13.5
				Thickness (in)	10	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior
		3.1.15	Walls_Cast-in-place_GroundFloor_ClassroomBlock_7"_1	Length (ft)	242.4	141.4
				Height (ft)	13.5	13.5
				Thickness (in)	7	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior
		3.1.17	Walls_Cast-in-place_GroundFloor_ClassroomBlock_4"	Length (ft)	365	121.67
				Height (ft)	13.5	13.5
				Thickness (in)	4	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior
		3.1.2	Walls_Cast-in-place_Basement_ClassroomBlock_1'6"	Length (ft)	338	507
				Height (ft)	10.83	10.83
				Thickness (in)	18	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
			Door Opening	Number of Doors	-	4
				Door Type	-	Steel Interior

		3.1.24	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_8"	Length (ft)	141	141
				Height (ft)	11.75	11.75
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior
		3.1.25	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_7"	Length (ft)	58	33.83
				Height (ft)	11.75	11.75
				Thickness (in)	7	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior
		3.1.27	Walls_Cast-in-place_Staircase_TypicalFloor_ClassroomBlock_10"	Length (ft)	61	50.81
				Height (ft)	11.75	11.75
				Thickness (in)	10	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.1.28	Walls_Cast-in-place_TypicalFloor_ClassroomBlock_1'3"	Length (ft)	1011	1263.75
				Height (ft)	11.75	11.75
				Thickness (in)	15	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
			Door Opening	Number of Doors	57	57
				Door Type	Wooded	Solid Wood Doors
		3.1.3	Walls_Cast-in-place_Basement_ClassroomBlock_10"	Length (ft)	46	38.33
				Height (ft)	10.83	10.83
				Thickness (in)	10	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior

		3.1.4	Walls_Cast-in-place_Basement_ClassroomBlock_7"	Length (ft)	450	262.5
				Height (ft)	10.83	10.83
				Thickness (in)	7	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior
			Door Opening	Number of Doors	-	0
				Door Type	-	0
		3.1.5	Walls_Cast-in-place_Basement_ClassroomBlock_9"_1	Length (ft)	286	214.5
				Height (ft)	10.83	10.83
				Thickness (in)	9	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior
			Door Opening	Number of Doors	-	0
				Door Type	-	0
		3.1.7	Walls_Cast-in-place_GroundFloor_ClassroomBlock_1'6"	Length (ft)	127	190.5
				Height (ft)	12.5	12.5
				Thickness (in)	18	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4 & 5	5
				Wall Type	Interior	Interior
			Door Opening	Number of Doors	12	12
				Door Type	Glazing	Aluminum Ext. Door 80% Glazing
			Window Opening	Number of Windows	18	18
				Total Window Area (ft2)	348	348
				Fixed/Operable	Fixed	Fixed
				Frame Type	Metal	Aluminum
				Glazing Type	Standard	Standard
				Thickness (in)	0.5	-

3.2 Office Block	3.2.1	Walls_Cast-in-place_Basement_OfficeBlock_9"_1	Length (ft)	150	112.5
			Height (ft)	10.83	10.83
			Thickness (in)	9	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Interior	Interior
	3.2.15	Walls_Stairs_PrecastConcrete_GroundFloor_OfficeBlock_6"	Length (ft)	89	44.5
			Height (ft)	6	6
			Thickness (in)	6	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Interior	Interior
	3.2.16	Walls_Cast-in-place_GroundFloor_OfficeBlock_6"_Height=3'	Length (ft)	27	13.5
			Height (ft)	3	3
			Thickness (in)	6	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Interior	Interior
	3.2.17	Walls_Cast-in-place_TypicalFloor_OfficeBlock_9"	Length (ft)	1267	950.25
			Height (ft)	8.75	8.75
			Thickness (in)	9	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Interior	Interior
		Door Opening	Number of Doors	126	126
			Door Type	Wooden	Hollow Core Wooden
	3.2.19	Walls_Cast-in-place_TypicalFloor_OfficeBlock_8"	Length (ft)	448	448
			Height (ft)	8.75	8.75
			Thickness (in)	8	8
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	4	5
			Wall Type	Interior	Interior
		Door Opening	Number of Doors	14	14
			Door Type	Wooden	Hollow Core Wooden

		3.2.20	Walls_Cast-in-place_Concrete_Southwest_Stairs_Basement_L2	Length (ft)	11.17	4.66
				Height (ft)	10.83	10.83
				Thickness (in)	5	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.2.21	Walls_Cast-in-place_Concrete_Southwest_Stairs_L3_Penthouse	Length (ft)	34.13	14.22
				Height (ft)	8	8
				Thickness (in)	5	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.2.22	Walls_Cast-in-place_Concrete_Southwest_Stairs_Penthouse	Length (ft)	2.25	0.9375
				Height (ft)	8	8
				Thickness (in)	5	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.2.4	Walls_Cast-in-place_Basement_OfficeBlock_8"	Length (ft)	286	286
				Height (ft)	10.83	10.83
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.2.5	Walls_Cast-in-place_Basement_OfficeBlock_6"	Length (ft)	42	21
				Height (ft)	10.83	10.83
				Thickness (in)	6	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior

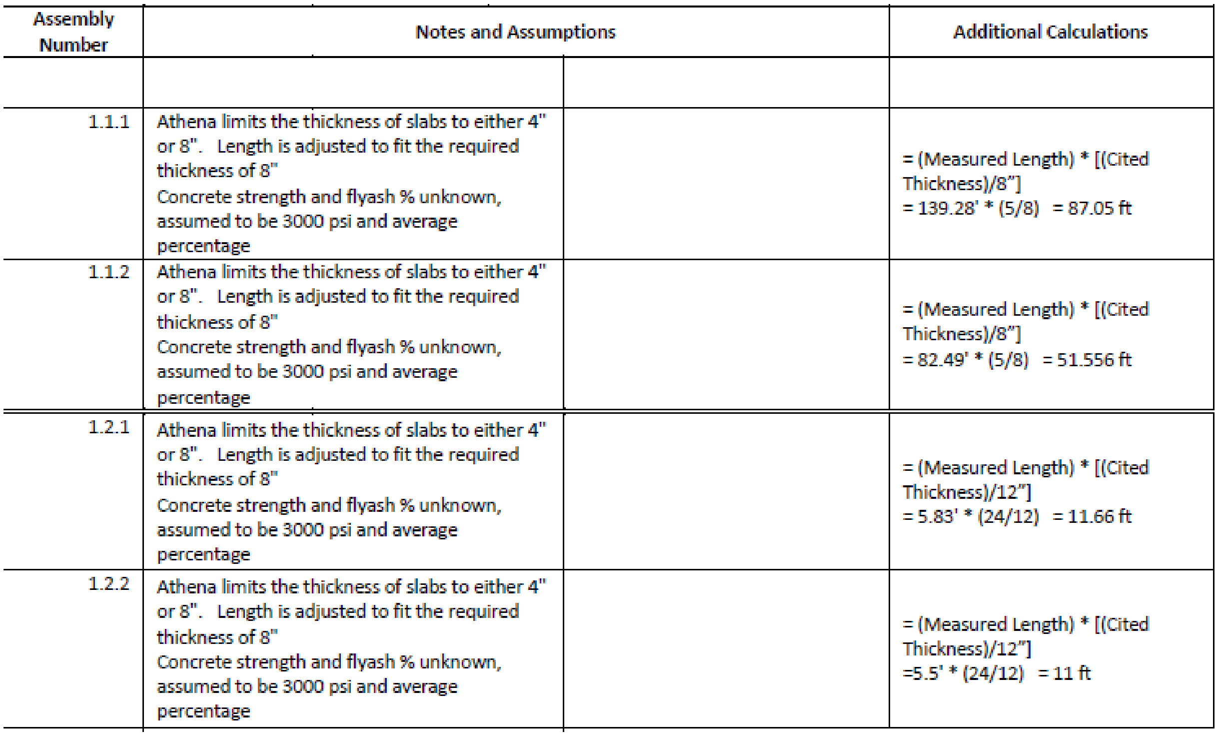
		3.2.6	Walls_Cast-in-place_Basement_OfficeBlock_1'2.5"	Length (ft)	46	55.58
				Height (ft)	10.83	10.83
				Thickness (in)	14.5	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.2.7	Walls_Cast-in-place_Basement_OfficeBlock_5"	Length (ft)	74	30.83
				Height (ft)	10.83	10.83
				Thickness (in)	5	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.2.8	Walls_Cast-in-place_Curb_Ground_OfficeBlock_8"_6'	Length (ft)	184	184
				Height (ft)	6	6
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.2.9	Walls_Cast-in-place_GroundFloor_OfficeBlock_8"	Length (ft)	168	168
				Height (ft)	12.5	12.5
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
			Envelope	Category	Insulation	Insulation
				Material	Styrofoam	Expanded Polystrene
				Thickness (in)	1	1
				Category	-	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"
				Thickness (in)	0.5	0.5
		3.2.10	Walls_Cast-in-place_Curb_Ground_OfficeBlock_8"_3'	Length (ft)	45	45
				Height (ft)	3	3
				Thickness (in)	8	8
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior

		3.2.11	Walls_Cast-in-place_GroundFloor_OfficeBlock_6"	Length (ft)	99	49.5
				Height (ft)	12.5	12.5
				Thickness (in)	6	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	4	5
				Wall Type	Interior	Interior
		3.5.1	Walls_Cast-in-place_TypicalFloors_ClassroomBlock	Length (ft)	774	580.5
				Height (ft)	11.75	11.75
				Thickness (in)	9	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Interior	Interior
		3.5.2	Walls_Cast-in-place_TypicalFloors_Office	Length (ft)	1869	1401.75
				Height (ft)	8.75	8.75
				Thickness (in)	4	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Interior	Interior
			Envelope	Category	Siding	Gypsum Board
				Material	Plaster	Gypsum Regular 1/2"

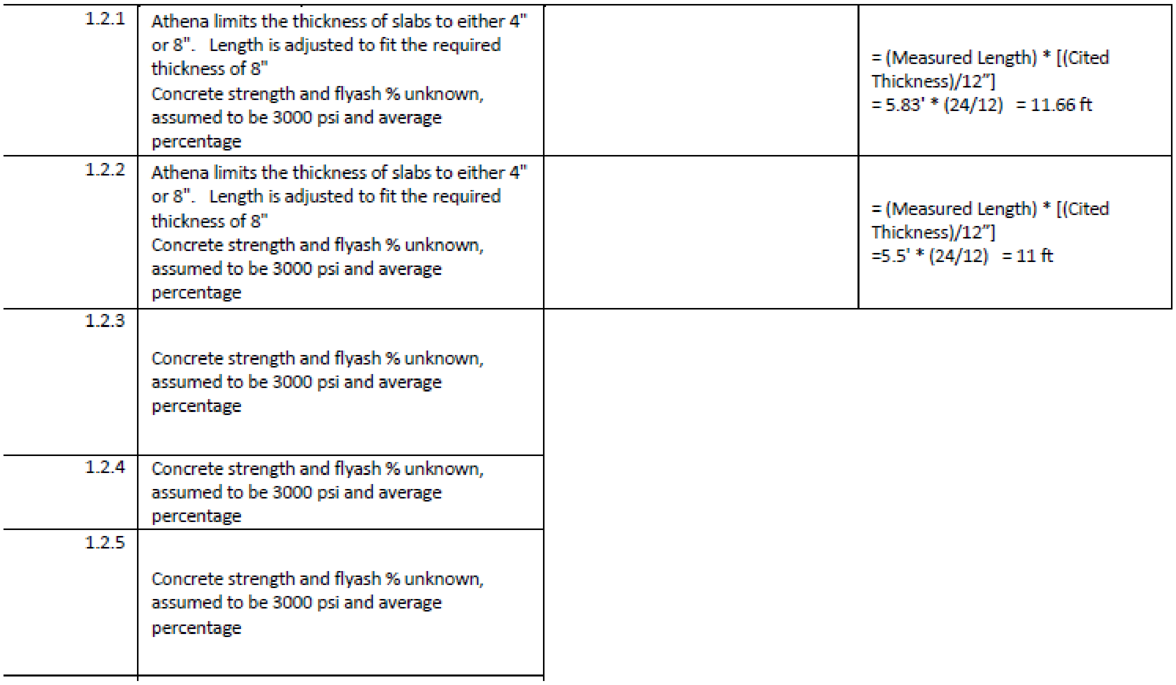
3.6 Concrete Blocks					
	3.6.1	Walls_ConcreteBlock_1'4"	Length (ft)	33.11	44.15
			Height (ft)	33.11	33.11
			Thickness (in)	16	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	5	5
			Wall Type	Interior	Interior
		Envelope	Category	Insulation	Insulation
			Material	Insulation Batt	Fibreglass Batt
			Thickness (in)	2	2
	3.6.2	Walls_ConcreteBlock_6"	Length (ft)	27.46	13.73
			Height (ft)	27.46	27.46
			Thickness (in)	6	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	5	5
			Wall Type	Interior	Interior
		Envelope	Category	Insulation	Insulation
			Material	Insulation Batt	Fibreglass Batt
			Thickness (in)	2	2
	3.6.3	Walls_ConcreteBlock_9"	Length (ft)	96.91	72.86
			Height (ft)	96.91	96.91
			Thickness (in)	9	12
			Concrete Strength (psi)	-	3000
			Concrete Flyash %	-	Average
			Rebar #	5	5
			Wall Type	Interior	Interior
		Envelope	Category	Insulation	Insulation
			Material	Insulation Batt	Fibreglass Batt
			Thickness (in)	2	2

		3.6.4	Walls_ConcreteBlock_1'3"	Length (ft)	30.20	37.75
				Height (ft)	30.2	30.2
				Thickness (in)	15	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Interior	Interior
			Envelope	Category	Insulation	Insulation
				Material	Insulation Batt	Fibreglass Batt
				Thickness (in)	2	2
		3.6.5	Walls_ConcreteBlock_11"	Length (ft)	48.71	44.65
				Height (ft)	48.71	48.71
				Thickness (in)	11	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Interior	Interior
			Envelope	Category	Insulation	Insulation
				Material	Insulation Batt	Fibreglass Batt
				Thickness (in)	2	2
		3.6.6	Walls_ConcreteBlock_7"	Length (ft)	68.94	40.22
				Height (ft)	68.94	68.94
				Thickness (in)	7	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Interior	Interior
			Envelope	Category	Insulation	Insulation
				Material	Insulation Batt	Fibreglass Batt
				Thickness (in)	2	2
		3.6.7	Walls_Cast-in-place_Stairs_North_10"	Length (ft)	7.62	6.35
				Height (ft)	7.62	7.62
				Thickness (in)	10	12
				Concrete Strength (psi)	-	3000
				Concrete Flyash %	-	Average
				Rebar #	5	5
				Wall Type	Interior	Interior

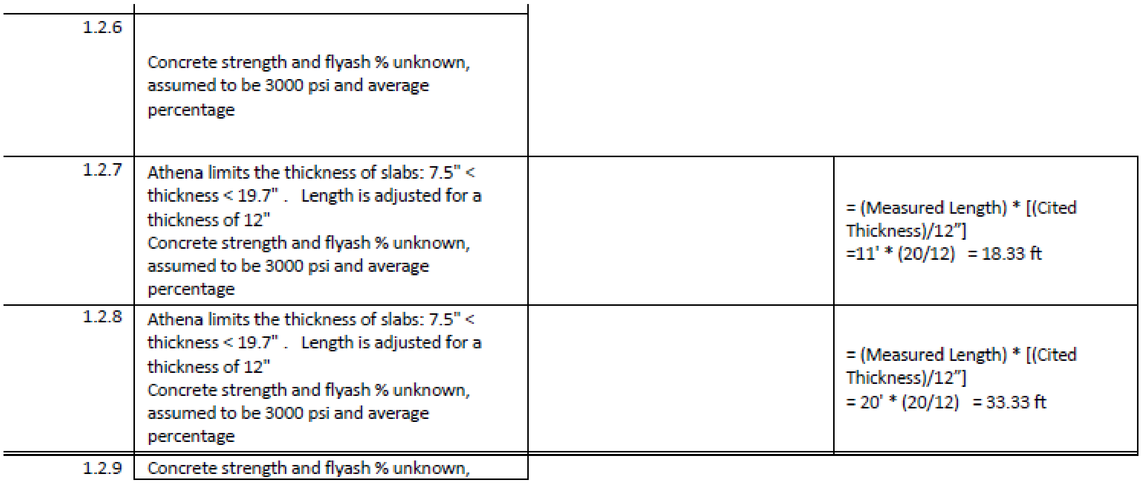
Annex D – Impact Estimator Input Assumption

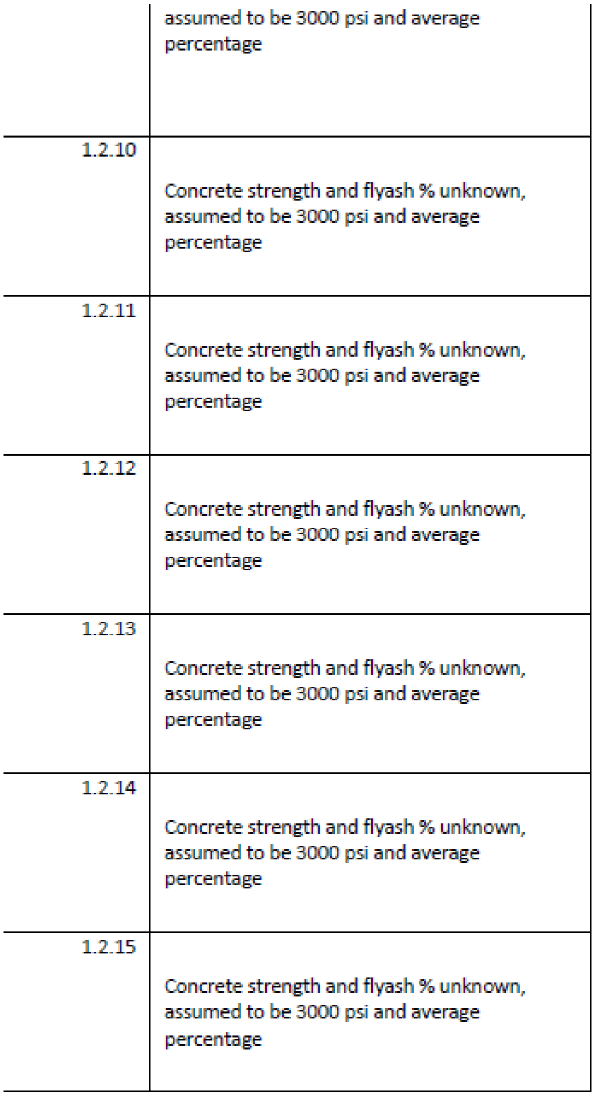


Assembly Number	Notes and Assumptions		Additional Calculations
1.1.1	Athena limits the thickness of slabs to either 4" or 8". Length is adjusted to fit the required thickness of 8" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		= (Measured Length) * [(Cited Thickness)/8"] = 139.28' * (5/8) = 87.05 ft
1.1.2	Athena limits the thickness of slabs to either 4" or 8". Length is adjusted to fit the required thickness of 8" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		= (Measured Length) * [(Cited Thickness)/8"] = 82.49' * (5/8) = 51.556 ft
1.2.1	Athena limits the thickness of slabs to either 4" or 8". Length is adjusted to fit the required thickness of 8" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		= (Measured Length) * [(Cited Thickness)/12"] = 5.83' * (24/12) = 11.66 ft
1.2.2	Athena limits the thickness of slabs to either 4" or 8". Length is adjusted to fit the required thickness of 8" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		= (Measured Length) * [(Cited Thickness)/12"] =5.5' * (24/12) = 11 ft

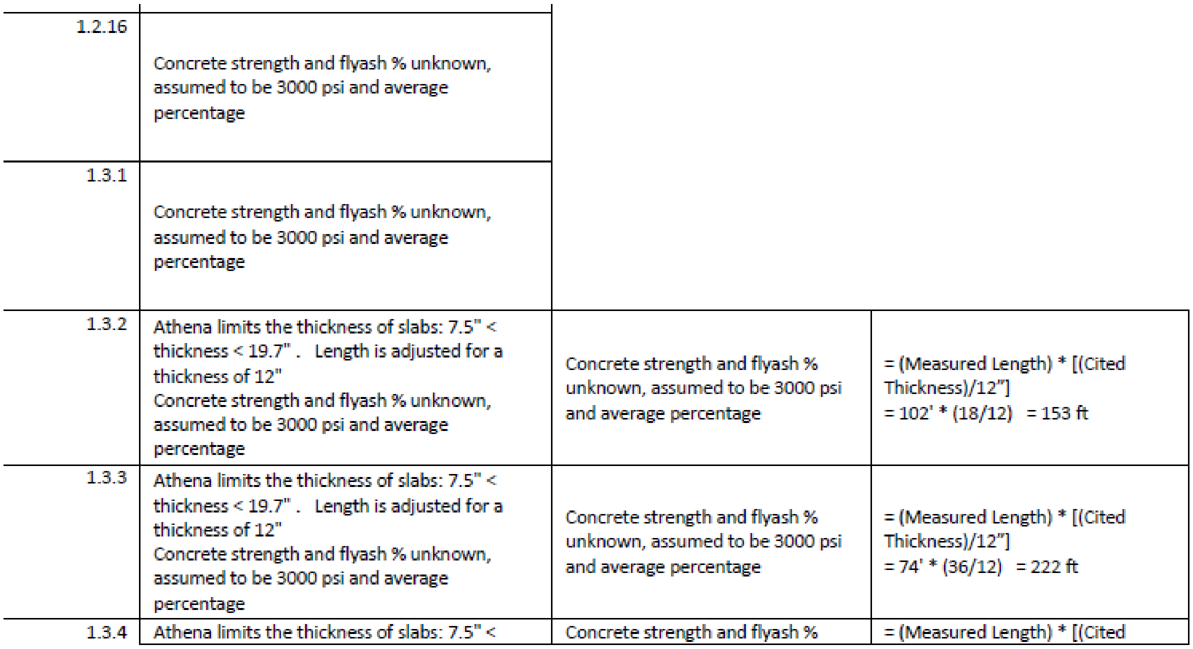


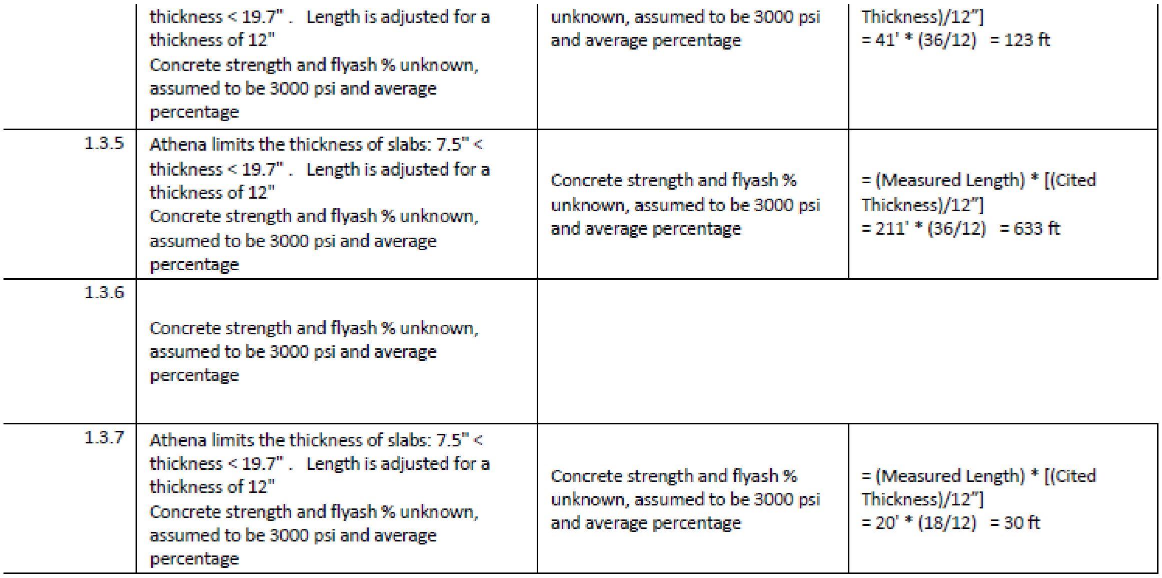
1.2.1	Athena limits the thickness of slabs to either 4" or 8". Length is adjusted to fit the required thickness of 8" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		= (Measured Length) * [(Cited Thickness)/12"] = 5.83' * (24/12) = 11.66 ft
1.2.2	Athena limits the thickness of slabs to either 4" or 8". Length is adjusted to fit the required thickness of 8" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		= (Measured Length) * [(Cited Thickness)/12"] =5.5' * (24/12) = 11 ft
1.2.3	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.4	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.5	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		





1.2.6	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.7	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		= (Measured Length) * [(Cited Thickness)/12”] =11' * (20/12) = 18.33 ft
1.2.8	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		= (Measured Length) * [(Cited Thickness)/12”] = 20' * (20/12) = 33.33 ft
1.2.9	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.10	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.11	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.12	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.13	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.14	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.2.15	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		



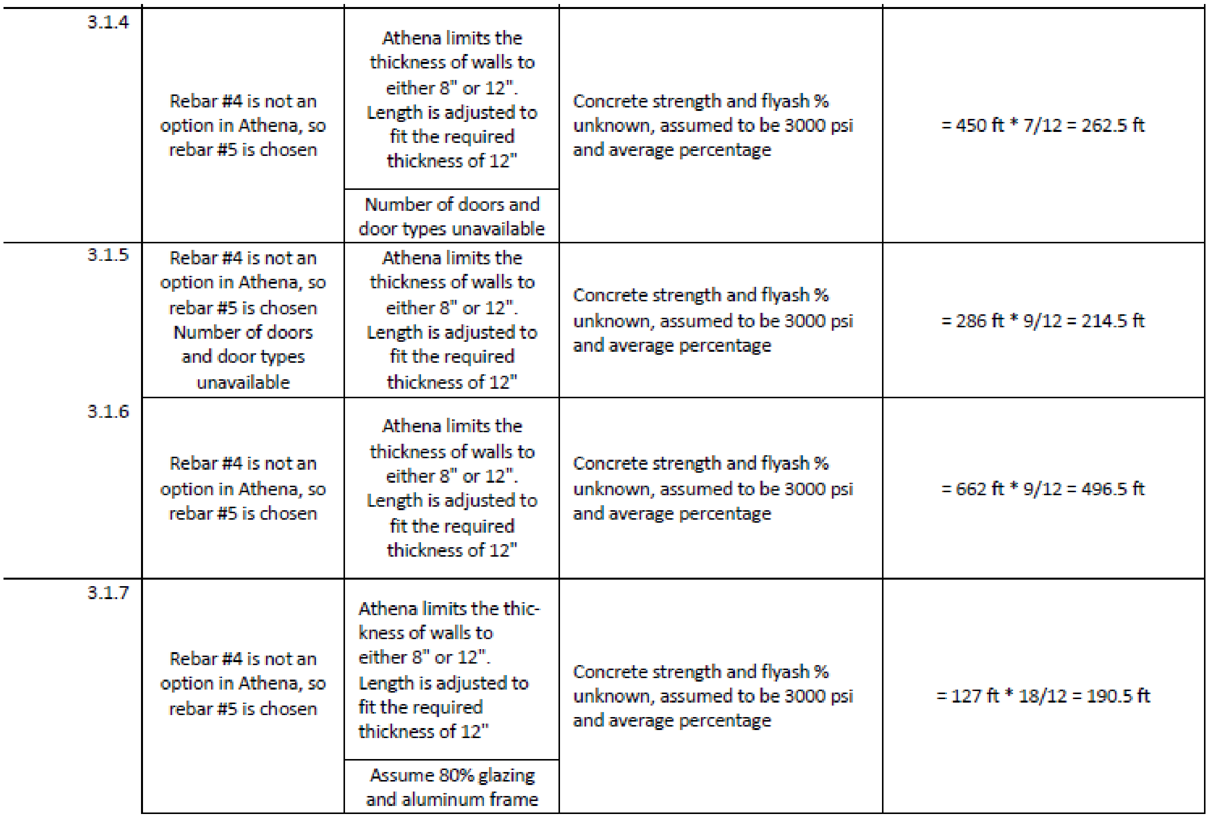


1.2.16	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.3.1	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.3.2	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12"] = 102' * (18/12) = 153 ft
1.3.3	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12"] = 74' * (36/12) = 222 ft
1.3.4	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12"] = 41' * (36/12) = 123 ft
1.3.5	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12"] = 211' * (36/12) = 633 ft
1.3.6	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.3.7	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12" Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12"] = 20' * (18/12) = 30 ft

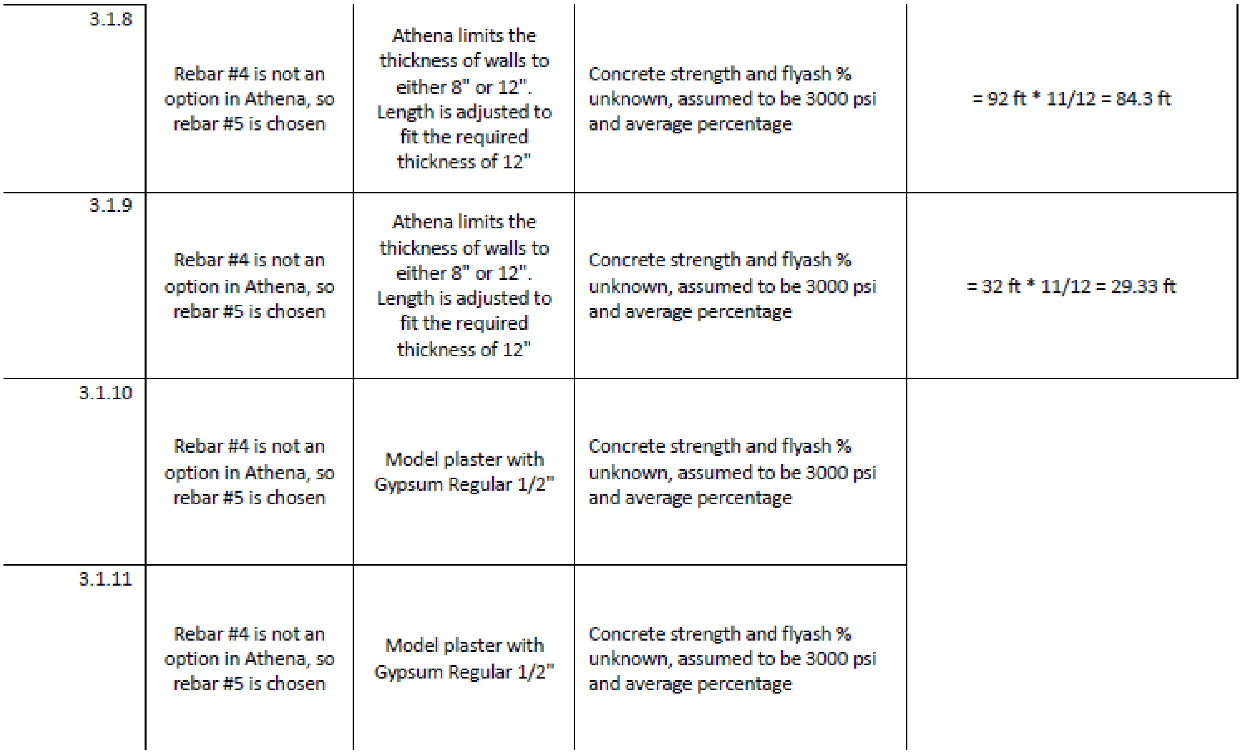
1.3.8	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage			
1.4.1	Rebar #4 is not an option in Athena for walls, so #5 is chosen	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.4.2	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage			
1.4.3	Rebar #4 is not an option in Athena for walls, so #5 is chosen	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
1.4.4	Rebar #4 is not an option in Athena for walls, so #5 is chosen	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage		
2.1.1	Live load is assumed to 60 psf for classrooms, theatres and labs. Live load is 100 psf for corridors, but since drawings don't specify areas, and corridor area negligible in comparison, 75 psf is assumed for slabs.	The area of slab was measured from Onscreen Takeoff, the span is limited to 32 feet and the width is calculated by area / 20 ft	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 3114 sf / 20 ft = 155.7 ft

2.1.2	Live load is assumed to 60 psf for classrooms, theatres and labs. Live load is 100 psf for corridors, but since drawings don't specify areas, and corridor area negligible in comparison, 75 psf is assumed for slabs.	The area of slab was measured from Onscreen Takeoff, the span is limited to 32 feet and the width is calculated by area / 20 ft	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 7703 sf / 20 ft = 385.15 ft
2.1.3	Live load is assumed to 60 psf for classrooms, theatres and labs. Live load is 100 psf for corridors, but since drawings don't specify areas, and corridor area negligible in comparison, 75 psf is assumed for slabs.	The area of slab was measured from Onscreen Takeoff, the span is limited to 32 feet and the width is calculated by area / 20 ft	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	=16653 sf / 20 ft =832.65 ft
2.1.4	Live load is assumed to 60 psf for classrooms, theatres and labs. Live load is 100 psf for corridors, but since drawings don't specify areas, and corridor area negligible in comparison, 75 psf is assumed for slabs.	The area of slab was measured from Onscreen Takeoff, the span is limited to 32 feet and the width is calculated by area / 20 ft	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 2211 sf / 20 ft = 110.55 ft
2.1.5	Live load is assumed to 60 psf for classrooms, theatres and labs. Live load is 100 psf for corridors, but since drawings don't specify areas, and corridor area negligible in comparison, 75 psf is assumed for slabs.	The area of slab was measured from Onscreen Takeoff, the span is limited to 32 feet and the width is calculated by area / 20 ft	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 33948 sf / 20 ft = 1697.4 ft
2.1.6	Live load is assumed to 60 psf for classrooms, theatres and labs. Live load is 100 psf for corridors, but since drawings don't specify areas, and corridor area negligible in comparison, 75 psf is assumed for slabs.	The area of slab was measured from Onscreen Takeoff, the span is limited to 32 feet and the width is calculated by area / 20 ft	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 456 sf / 20 ft = 22.8 ft
2.1.7	Live load is assumed to 60 psf for classrooms, theatres and labs. Live load is 100 psf for corridors, but since drawings don't specify areas, and corridor area negligible in comparison, 75 psf is assumed for slabs.	The area of slab was measured from Onscreen Takeoff, the span is limited to 32 feet and the width is calculated by area / 20 ft	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 5200 sf / 20 ft = 260 ft
2.2.1	Live load is assumed	Floors 2 to 4: 92 bays	Concrete strength and flyash %	Total number of bays = 3 x 92 = 276

	to 60 psf for classrooms, theatres and labs. Live load is 100 psf for corridors, but since drawings don't specify areas, and corridor area negligible in comparison, 75 psf is assumed for slabs.	on each floor Topping in Athena refers to 50 mm concrete topping	unknown, assumed to be 3000 psi and average percentage	
3.1.1	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Model plaster with Gypsum Regular 1/2"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.1.2	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12" Number of doors and door types unavailable - assume 4 doors from stairs entrance	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 338 ft * 18/12 = 507 ft
3.1.3	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 46 ft * 10/12 = 38.33 ft



3.1.4	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12" Number of doors and door types unavailable	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 450 ft * 7/12 = 262.5 ft
3.1.5	Rebar #4 is not an option in Athena, so rebar #5 is chosen Number of doors and door types unavailable	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 286 ft * 9/12 = 214.5 ft
3.1.6	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 662 ft * 9/12 = 496.5 ft
3.1.7	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12" Assume 80% glazing and aluminum frame	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 127 ft * 18/12 = 190.5 ft



3.1.8	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 92 ft * 11/12 = 84.3 ft
3.1.9	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 32 ft * 11/12 = 29.33 ft
3.1.10	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Model plaster with Gypsum Regular 1/2"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.1.11	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Model plaster with Gypsum Regular 1/2"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	

3.1.12	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 38 ft * 10/12 = 31.67 ft
3.1.13	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage Assume 80% glazing	= 11 ft * 24/12 = 22 ft
3.1.14	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 69 ft * 13/12 = 74.75 ft
3.1.15	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 242.4 ft * 7/12 = 141.4 ft
3.1.16	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage Model Plaster with Gypsum Regular 1/2"	= 95.6 ft * 7/12 = 55.77 ft
3.1.17	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 365 ft * 4/12 = 121.67 ft
3.1.18	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 35 ft * 22/12 = 64.17 ft
3.1.19	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 84 ft * 20/12 = 140 ft
3.1.20	Rebar #4 is not an option in Athena, so rebar #5 is chosen		Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	

3.1.21	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 67 ft * 6/12 = 33.5 ft
3.1.22	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage Model Plaster with Gypsum Regular 1/2"	= 143 ft * 9/12 = 107.25 ft
3.1.23	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage Model Plaster with Gypsum Regular 1/2"	= 2 ft * 11/12 = 1.83 ft
3.1.24	Rebar #4 is not an option in Athena, so rebar #5 is chosen		Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.1.25	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 58 ft * 7/12 = 33.83 ft
3.1.26	Rebar #3 is not an option in Athena, so	Athena limits the thickness of walls to	Concrete strength and flyash % unknown, assumed to be 3000 psi	= 503 ft * 6/12 = 251.5 ft

	rebar #5 is chosen	either 8" or 12". Length is adjusted to fit the required thickness of 12"	and average percentage	
3.1.27	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 61 ft * 10/12 = 50.81 ft
3.1.28	Rebar #4 is not an option in Athena, so rebar #5 is chosen	1. Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12" 2. Architectural drawings doesn't show partition walls, position of walls and number of doors and door type are based on current floor plan	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 1011 ft * 15/12 = 1263.75 ft
3.1.29		Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 60.89 ft * 11/12 = 55.82 ft
3.1.30	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 61.86 ft * 6/12 = 30.93 ft

3.1.31		Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 10.39 ft * 6/12 = 5.2 ft
3.1.32		Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 12.49 ft * 16/12 = 16.65 ft
3.2.1	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 150 ft * 9/12 = 112.5 ft
3.2.2	Rebar #4 is not an option in Athena, so	Athena limits the thickness of walls to	Concrete strength and flyash % unknown, assumed to be 3000 psi	= 136 ft * 9/12 = 102 ft

	rebar #5 is chosen	either 8" or 12". Length is adjusted to fit the required thickness of 12"	and average percentage	
3.2.3	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 17 ft * 10/12 = 14.17 ft
3.2.4	Rebar #4 is not an option in Athena, so rebar #5 is chosen		Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.2.5	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 42 ft * 6/12 = 21 ft
3.2.6	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 46 ft * 14.5/12 = 55.58 ft
3.2.7	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 74 ft * 5/12 = 30.83 ft
3.2.8	Rebar #4 is not an option in Athena, so rebar #5 is chosen		Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.2.9	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Model plaster with Gypsum Regular 1/2"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.2.10	Rebar #4 is not an option in Athena, so rebar #5 is chosen		Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.2.11	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 99 ft * 6/12 = 49.5 ft
3.2.12	Rebar #4 is not an option in Athena, so	Athena limits the thickness of walls to	Concrete strength and flyash % unknown, assumed to be 3000 psi	= 136 ft * 5.5/12 = 62.33 ft

	rebar #5 is chosen	either 8" or 12". Length is adjusted to fit the required thickness of 12"	and average percentage Model Plaster with Gypsum Regular 1/2"	
3.2.13	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 207 ft * 7.75/12 = 133.69 ft
3.2.14	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 32 ft * 5/12 = 13.33 ft
3.2.15	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 89 ft * 6/12 = 44.5 ft
3.2.16	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 27 ft * 6/12 = 13.5 ft
3.2.17	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 1267 ft * 9/12 = 950.25 ft
		Assume hollow core wooden doors		

3.2.18	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage Model Plaster with Gypsum Regular 1/2"	= 56 ft * 5.5/12 = 25.67 ft
3.2.19	Rebar #4 is not an option in Athena, so rebar #5 is chosen		Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.2.20	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 11.17 ft * 5/12 = 4.66 ft
3.2.21	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12".	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 34.13 ft * 5/12 = 14.22 ft

		Length is adjusted to fit the required thickness of 12"		
3.2.22	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 2.25 ft * 5/12 = 0.9375 ft
3.2.23	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 159 ft * 6/12 = 79.5 ft
3.2.24	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 50 ft * 9/12 = 37.5 ft
3.2.25	Rebar #4 is not an option in Athena, so rebar #5 is chosen		Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.3.1	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 82 ft * 11/12 = 75.17 ft
3.3.2			Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	
3.3.3	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 10 ft * 7/12 = 5.83 ft
3.4.1	Rebar #4 is not an option in Athena, so rebar #5 is chosen	1. Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12" 2. Model mullions as rectangular blocks 3. To model both operable and fixed windows, divide the wall area by 2 4. Athena does not have precast walls, model as cast in place	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 525 ft * 7"/12" / 2 = 153.125 ft

		5. To avoid double counting window frame, combine two fixed window panes together and model as one		
3.4.2	Rebar #4 is not an option in Athena, so rebar #5 is chosen	1. Athena limits the thickness of wall to either 8" or 12". Length is adjusted to fit the required thickness of 12" 2. Model mullions as rectangular blocks 3. To model both operable and fixed windows, divide the wall area by 2 4. Athena does not have precast walls, model as cast in place 5. To avoid double counting window frame, combine two fixed window panes together and model as one	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 429 ft * 24"/12" / 2 = 429 ft

3.4.3	Rebar #4 is not an option in Athena, so rebar #5 is chosen	1. Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12" 2. Model mullions as rectangular blocks 3. To model both operable and fixed windows, divide the wall area by 2 4. Athena does not have precast walls, model as cast in place	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 1428 ft * 7"/12" / 2 = 416.5 ft
				=1360 sf * 0.0635 / 0.0217 = 3980 sf
		Assume hollow core wooden doors		
3.5.1	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 774 ft * 9/12 = 580.5 ft
3.5.2	Rebar #4 is not an	Athena limits the	Athena limits the thickness of walls	= 1869 ft * 9/12 = 1401.75 ft

	option in Athena, so rebar #5 is chosen	thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	to either 8" or 12". Length is adjusted to fit the required thickness of 12" 1/2" plaster modeled with gypsum regular 1/2"	
3.6.1	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 33.11 ft * 16/12 = 44.15 ft
3.6.2	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 27.46 ft * 6/12 = 13.73 ft
3.6.3	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 96.91 ft * 9/12 = 72.68 ft
3.6.4	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 30.2 ft * 15/12 = 37.75 ft
3.6.5	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 48.71 ft * 11/12 = 44.65 ft
3.6.6	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 68.94 ft * 7/12 = 40.22 ft
3.6.7	Rebar #4 is not an option in Athena, so rebar #5 is chosen	Athena limits the thickness of walls to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 7.62 ft * 10/12 = 6.35 ft
4.1.1	Assume organic felt for extruded polystyrene	Span is calculated by the weighted average method		Span = Total Area / (Bay Size A + Bay Size B) = 8626 sf / (40 in / 12 in) = 17.97 ft
4.2.1	Live load is specified at 27 psf, but Athena only provides	Total Roof Area / Supported Span = Roof Width	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 3277 sf / 13.33 ft = 245.84 ft

	choices of 45, 60 and 100 psf Assume organic felt for extruded polystyrene			
4.2.2	Live load is specified at 27 psf, but Athena only provides choices of 45, 60 and 100 psf Assume organic felt for extruded polystyrene	Total Roof Area / Supported Span = Roof Width	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 5987 sf / 10 ft = 598.7 ft
4.2.3	Live load is specified at 27 psf, but Athena only provides choices of 45, 60 and 100 psf Assume organic felt for extruded polystyrene	Total Roof Area / Supported Span = Roof Width	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 5887 sf / 10 ft = 588.7 ft
4.2.4	Live load is specified at 27 psf, but Athena only provides choices of 45, 60 and 100 psf Assume organic felt for extruded polystyrene	Total Roof Area / Supported Span = Roof Width	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 1401 sf / 10 ft = 140.1 ft
4.2.5	Rebar #3 & 4 is not an option in Athena, so rebar #5 is chosen	1. While this is part of the roof on the penthouse, it is a hanging concrete block, therefore it is modelled as a wall 2. Athena limits the thickness of slabs to either 8" or 12". Length is adjusted to fit the required thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= 516 ft * 3/12 = 129 ft

5.1.1		Bay size is calculated by supported area / (supported span * number of beams) Bay size is limited to be between 10 to 40 ft, adjust supported span to fit limitation, set bay size to 35 ft	Assume supported live load is 100 psf	= 15188 sf / (13.33 ft * 24) = 47.5 ft = 13.33 ft * 47.5 ft / 35 ft = 18.1 ft
5.1.2		Span is calculated by weighted average method Bay size is calculated	Assume supported live load is 100 psf	= [(Area A * Bay Size A) + (Area B * Bay Size B) + (Area C * Bay Size C)] / Total Area = [(11215*27.5) + (2247*12) + (6704*13.75)] / (11215+2247+6704) = 21.2 ft = 20166 sf / (21.2 ft * 40) =23.8 ft

		from total area divided by supported span and number of beams		
5.1.3		Bay size entered in Athena is the average bay size Supported span is calculated from total area divided by bay size and number of beams	Assume supported live load is 100 psf	= (16.75 ft + 19.5 ft + 16.75 ft) / 3 = 17.67 ft = (5316) sf / (17.67 ft * 19) =15.83 ft
5.2.1		Floor height is the average of the three floors	Assume supported live load is 100 psf	
5.2.2	Assume supported live load is 100 psf			
5.2.3	Assume supported live load is 100 psf			
5.2.4		Bay size entered in Athena is the average bay size	Assume supported live load is 100 psf	= (16.75 ft + 19.5 ft + 16.75 ft) / 3 = 17.67 ft
5.2.5		Bay size entered in Athena is the average bay size	Assume supported live load is 100 psf	= (16.75 ft + 19.5 ft + 16.75 ft) / 3 = 17.67 ft
6.1.1	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12"] = 25.71' * (7/12) = 15 ft
6.1.2	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12"] = 6.68' * (7/12) = 3.9 ft
6.1.3	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12"] = 12' * (7/12) = 7 ft

6.1.4	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 9' * (4/12) = 3 ft
6.1.5	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 48' * (3/12) = 12 ft
6.1.6	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 12' * (4/12) = 4 ft
6.1.7	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 60' * (4/12) = 20 ft
6.1.8	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 42' * (6/12) = 21 ft
6.1.9	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 99' * (4/12) = 33 ft
6.1.10	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 136' * (3/12) = 34 ft
6.1.11	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 224' * (3/12) = 46 ft
6.1.12	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 16' * (3/12) = 4 ft
6.1.13	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 36' * (3/12) = 9 ft

6.1.14	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 16' * (3/12) = 4 ft
6.1.15	Rebar #3 is not an option in Athena, #4 is chosen instead	Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 112' * (3/12) = 28 ft
6.1.16		Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 36' * (3/12) = 9 ft
6.1.17		Athena limits the thickness of slabs: 7.5" < thickness < 19.7" . Length is adjusted for a thickness of 12"	Concrete strength and flyash % unknown, assumed to be 3000 psi and average percentage	= (Measured Length) * [(Cited Thickness)/12”] = 16' * (3/12) = 4 ft