Project Documentation

1 Abstract

EnerPHit factory building in Katunayake, Sri Lanka

1.1 Data of building

17. Year of Construction

Year of construction	2016	**Space cooling**	**183** **kWh/(m^{2}a)**
U-value external wall	0.33 W/(m^{2}K)		
U-value basement slab	5.79 W/(m^{2}K)	**Primary Energy Renewable (PER)**	164 kWh/(m^{2}a)
U-value roof	0.18 W/(m^{2}K)	**Generation of renewable energy**	19 kWh/(m^{2}a)
U-value window	1.81 W/(m^{2}K)	**Non-renewable Primary Energy (PE)**	344 kWh/(m^{2}a)
Heat recovery	69 %	Pressure test n_{50}	0.8 h-1
Special features	High-performing curtain wall with low absorption or highly reflective to reduce cooling loads. Highly reflective Roof. Wrap around heat pipes in primary AHUs for passive dehumidification reheat.		

1.5 Specialties

18. Information about the design/ Architecture

The project's location in a hot and humid climate, combined with its use as a manufacturing facility, resulted in a heightened focus on strategies to reduce gains from both the sun and from equipment and occupants in the space. The existing building's steel structure was primarily preserved for the renovation with additional framing added as required. The perimeter of the building features long roof overhangs as well as exterior window shading screens to reduce solar gains in the building. A highly efficient double pane curtain wall system with ultra-low solar heat gain glazing was used to further reduce cooling loads. EIFS was used at the opaque portions of the façade to create a continuous thermal and air tight enclosure around the building. To further reduce thermal bridging, thermal breaks were used at steel attachments for the window screens and Aerolon paint was used on existing steel members that were penetrating the continuous insulation layer. At the project's completion, the building tested at whole building air tightness of 0.78 ACH50.

19. Information about the building services

Ventilation to the building is provided by 69% efficient energy recovery ventilators (ERVs) which help keep heat and humidity out of the building year-round. The primary cooling system in the building is a variable refrigerant flow (VRF) system. 2 large air handling units with heat pump coils provide cooling to the primary work floor. These air handling units feature wrap around heat pipes to passively provide extra dehumidification / reheat capacity to the system. These heat pipes save the project approximately 108,000 kWh/yr in dehumidification energy alone. Given the project's unique typology as a manufacturing facility, detailed surveys and analysis of the process loads in the spaces were done at multiple iterations of the project to ensure internal loads were being modelled properly.

20. (if involved) Information about the building physics

N/A

21. (if involved) Information about the structural design

See notes regarding structure in section 18.

Architect	Jordan Parnass Digital Architecture http://jpda.net/
Mechanical engineering	Chandana Dalugoda Consultants http://www.chandanadalugoda.net/
MEP	Kosala Kamburadeniya PE
Structural engineering	Ajith Vandebona PE
Passive House project planning	Dylan Martello, Steven Winter Associates www.swinter.com

Certifying body	Dragos Arnautu, Passive House Institute

	https://passivehouse.com/	
Certification ID	Project-ID (www.passivehouse-database.org)	6030

Author of project documentation	
Dylan Martello (Steven Winter Associates)	
Date	**Signature**
11/19/2021	

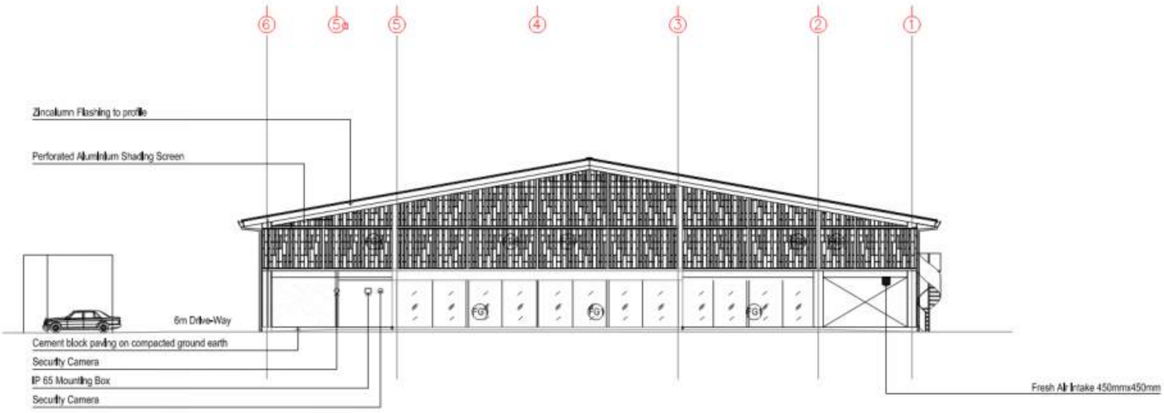
2. Abstract

Steven Winter Associates, Inc. (SWA) worked remotely with a project team across the world to retrofit an outdated factory in Katunayake, Sri Lanka and turn it into an EnerPHit Passive House certified garment manufacturing facility. Jordan Parnass Digital Architecture, the Passive House Designer for the project, recruited SWA to provide technical assistance to the project team. SWA services for this project include Passive House design analysis and recommendations, mechanical design review, energy and thermal bridging modelling, as well as testing and verification required for Passive House certification.

The team enlisted the guidance of the Passive House Institute (PHI) early on in the project's development to tackle the many complexities associated with the EnerPHit standard - a Passive House certification that was designed by PHI for the renovation of existing buildings. The project's location in a hot and humid climate, combined with its use as a manufacturing facility, resulted in a heightened focus on strategies to reduce gains from both the sun and from equipment and occupants in the space. A high-performing curtain wall, with a solar heat gain coefficient of 0.22, was designed in conjunction with strategically designed overhangs and external shading screens to reduce the overall heat gain into the building.

The opaque portions of the thermal envelope feature an Exterior Insulated Finish System (EIFS) to continuously wrap both existing and new structural components in insulation with minimal thermal bridging. All exterior surfaces coatings have been specified as low absorption or highly reflective to further reduce cooling loads. Mechanical systems include advanced dehumidification controls that utilize waste heat from the cooling system to enhance the dehumidification capacity. Controlling the humidity in the space is not only essential for Passive House certification, but also for ensuring optimal thermal comfort for occupants.

3. Building Elevations

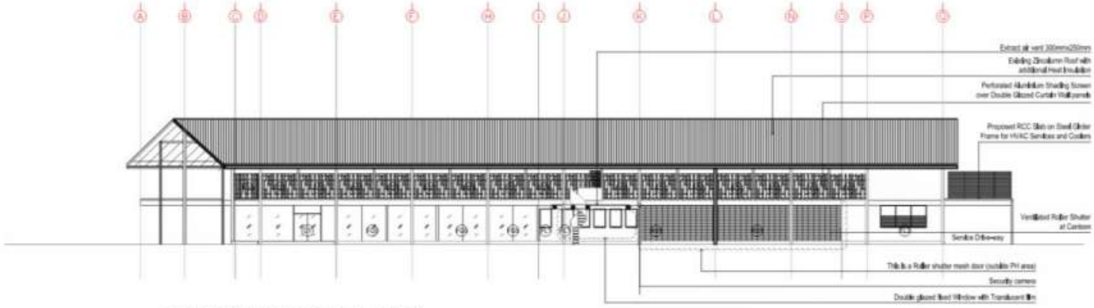


ELEVATION TO SOUTH - WEST

SCALE 1:200

ELEVATION TO NORTH - WEST

SCALE 1:200



ELEVATION TO SOUTH - EAST

SCALE 1:200

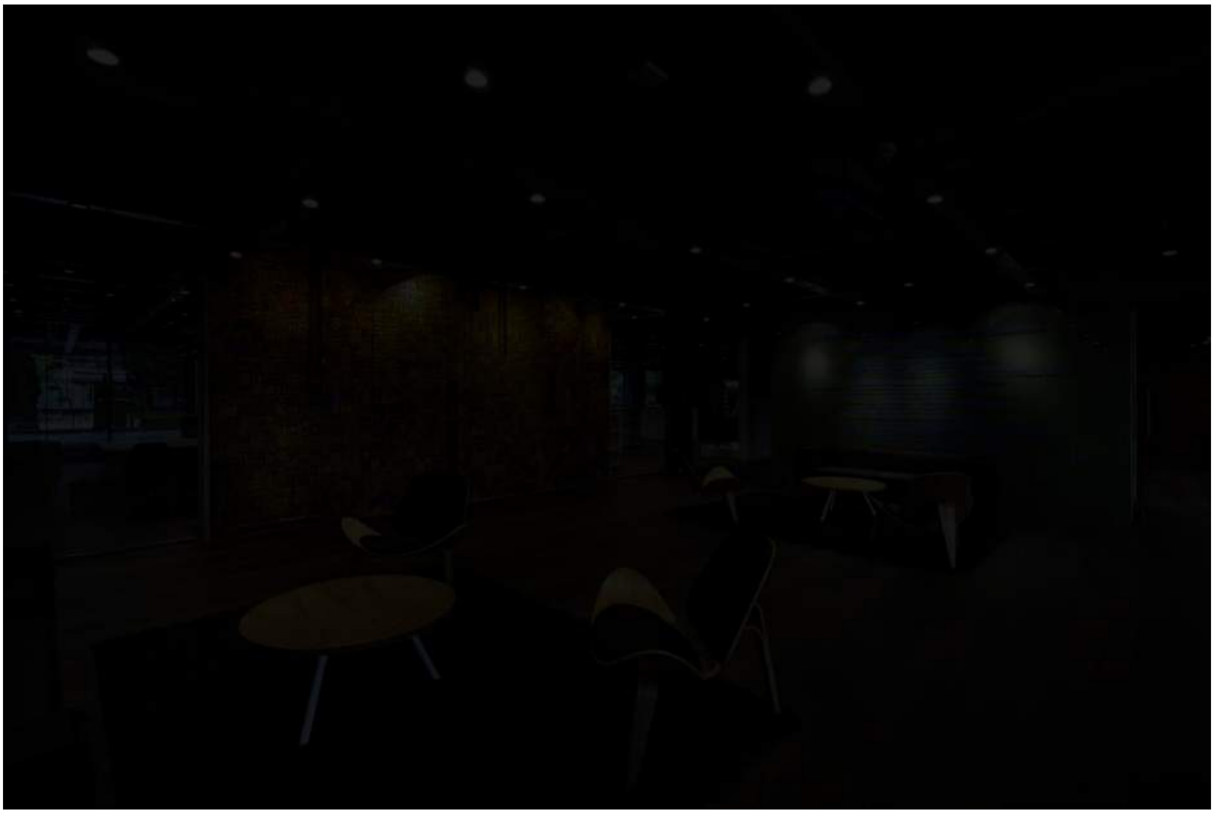
ELEVATION TO NORTH - EAST

SCALE 1:200

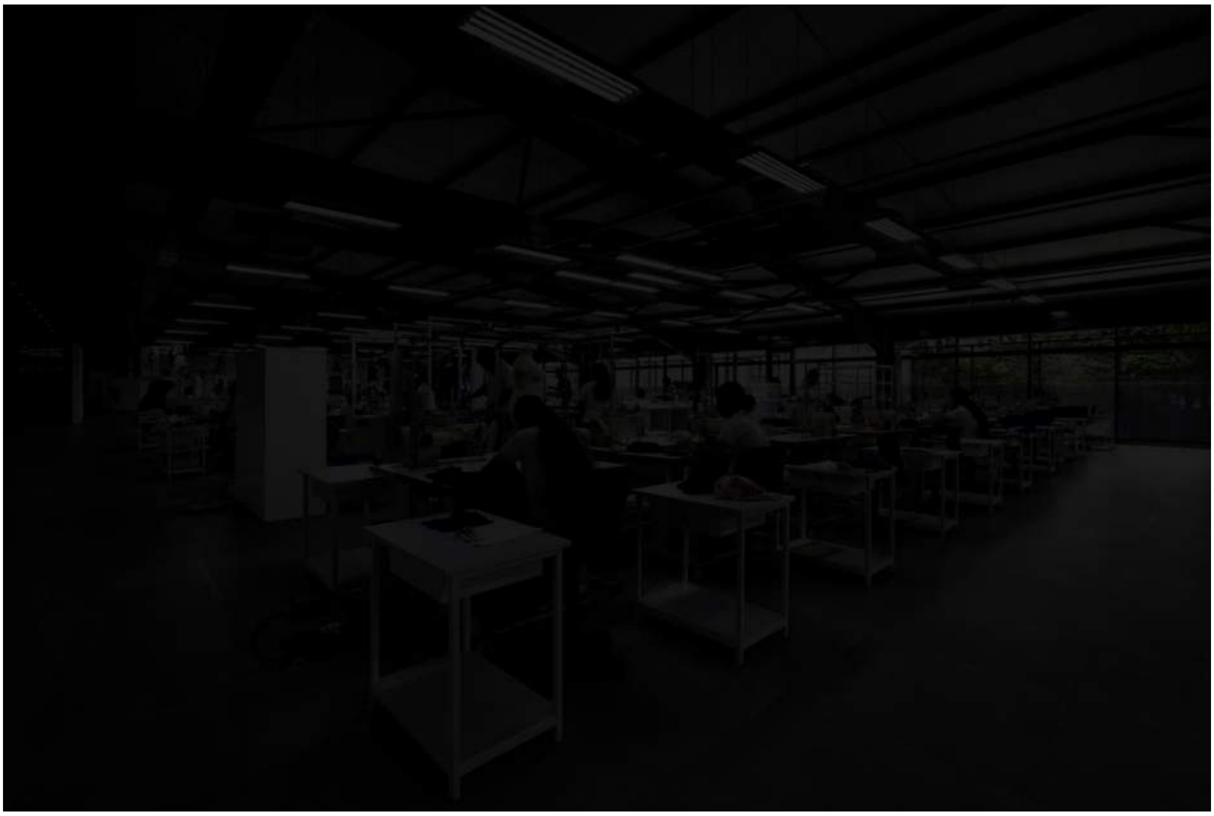
View from East. Photo courtesy of Ganidu Balasuriya Photography (2018)

View from West. Photo courtesy of Ganidu Balasuriya Photography (2018)

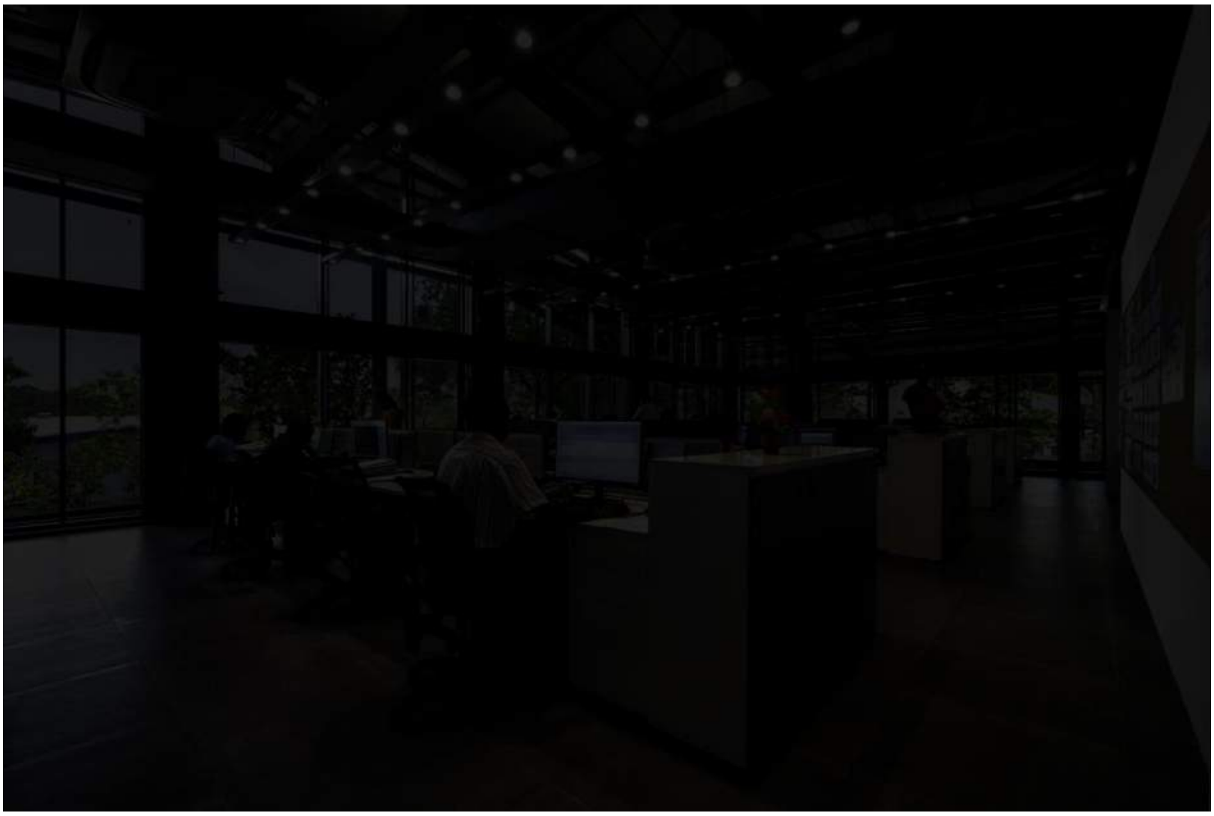
4. Exemplary photo from the inside of the building



Interior Ground Floor Entry. Photo courtesy of Ganidu Balasuriya Photography (2018)

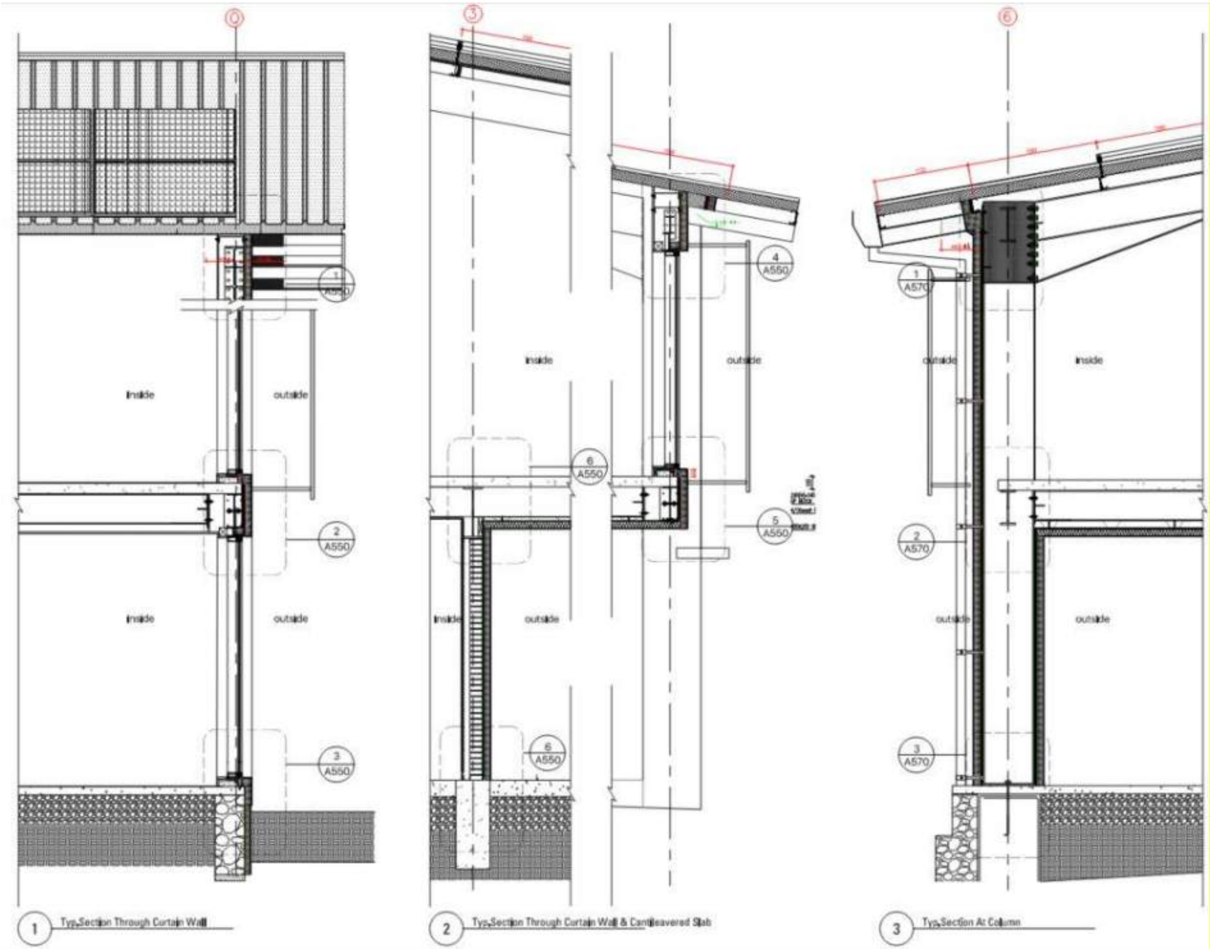


Interior 2nd Floor. Photo courtesy of Ganidu Balasuriya Photography (2018)



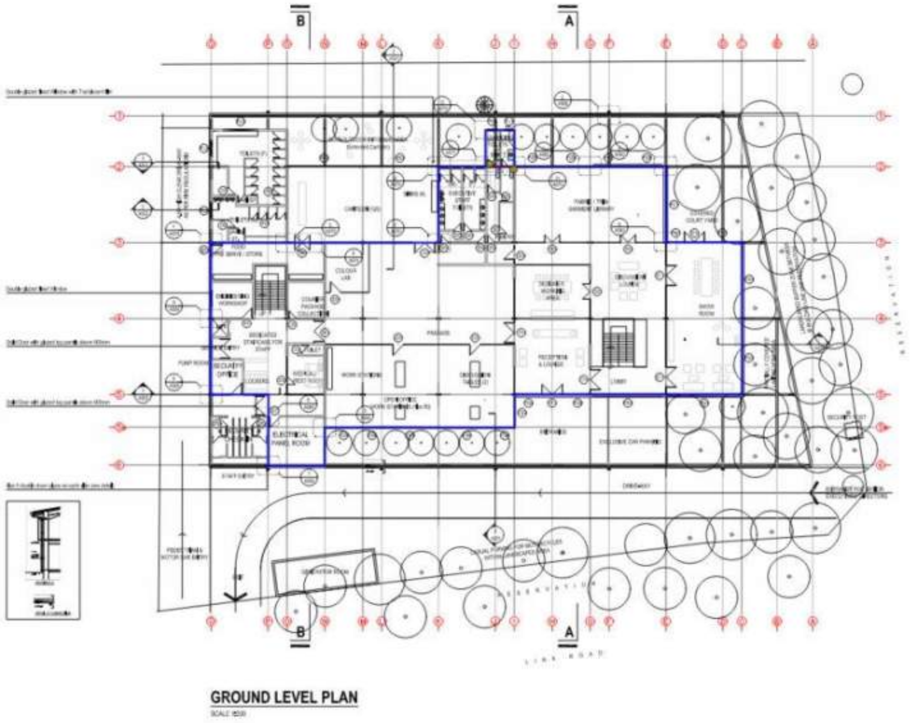
Interior 2nd Floor. Photo courtesy of Ganidu Balasuriya Photography (2018)

5. Sectional view of the building

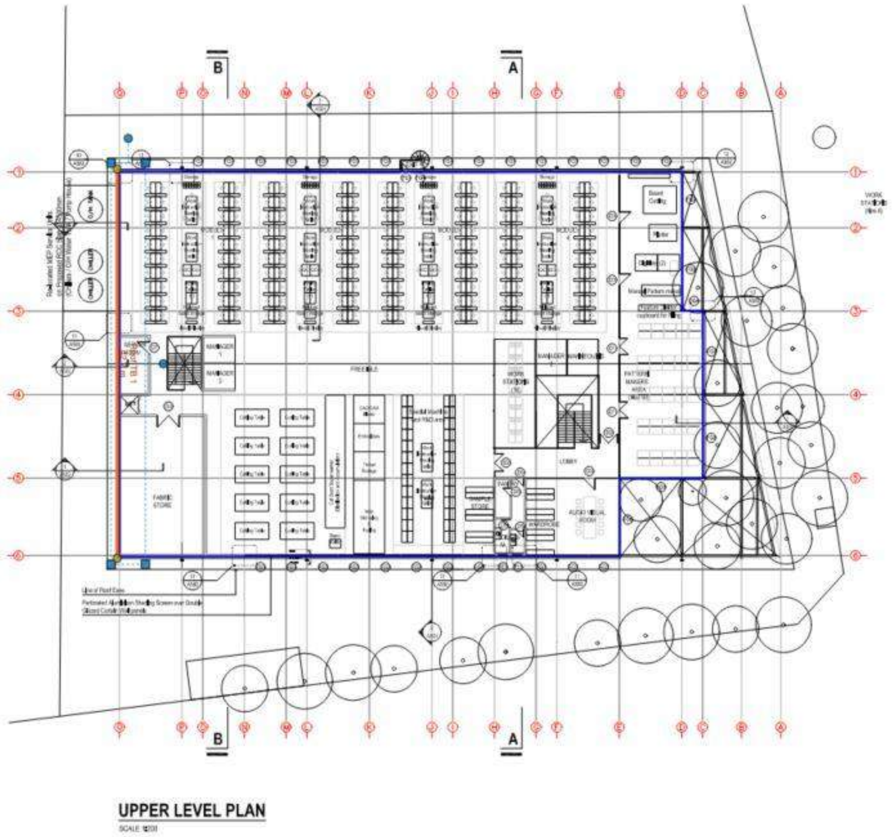


Select wall sections. Courtesy of Jordan Parnass Digital Architecture (JPDA).

6. Floor plans



Ground Floor Plan. Courtesy of Jordan Parnass Digital Architecture (JPDA).



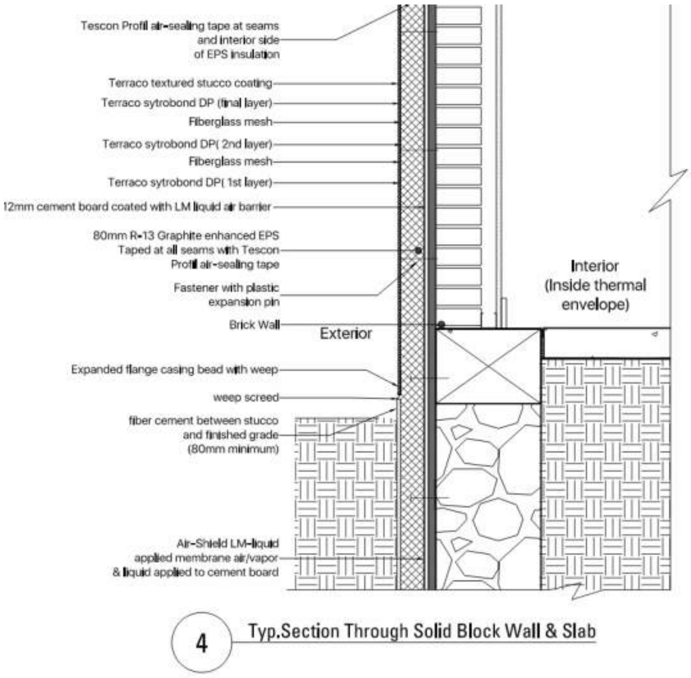
2nd Floor Plan. Courtesy of Jordan Parnass Digital Architecture (JPDA).

7. Construction of floor slab / basement ceiling

Existing floor slab remained uninsulated. It was concluded that no significant energy or comfort benefits would've resulted from insulating this slab.

8. Construction of the exterior walls

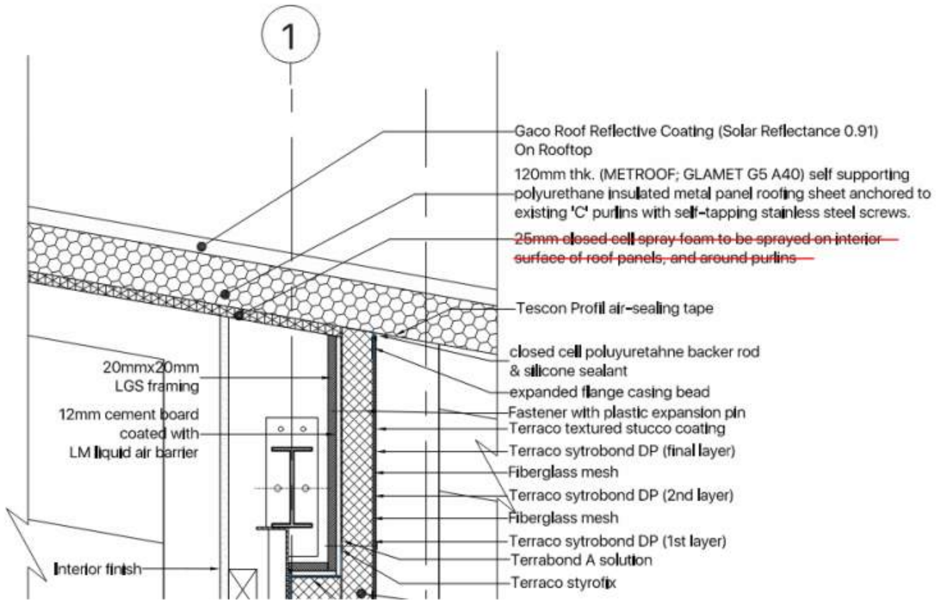
The exterior walls were built around the existing steel structure to limit thermal bridging on the project. Brick was the primary backup material for the exterior wall structure. To the exterior of the brick is a 12mm cement board layer which acted as the substrate for the continuous fluid applied air barrier. To the exterior of the cement board and air barrier is an 80mm thick EPS insulation layer with a drainage layer behind it and stucco on the exterior to complete the building exterior insulated finish system (EIFS). The exterior wall has a U-value of U-0.329 $W/m^2.K$.



Typical Exterior Wall Detail. Courtesy of Jordan Parnass Digital Architecture (JPDA).

9. Construction roof / ceiling of the top floor

The existing steel structure to support the roof was largely maintained for the retrofit. The primary roofing system is a 120mm self-supporting polyurethane insulated metal panel system. The roof has a U-value of U-0.182 W/m^2.K. To reduce thermal transmission through the roof structure, a highly reflective coating was applied to the exterior face of the roofing panels. Air sealing tape was applied at the roof to wall air barrier connections.

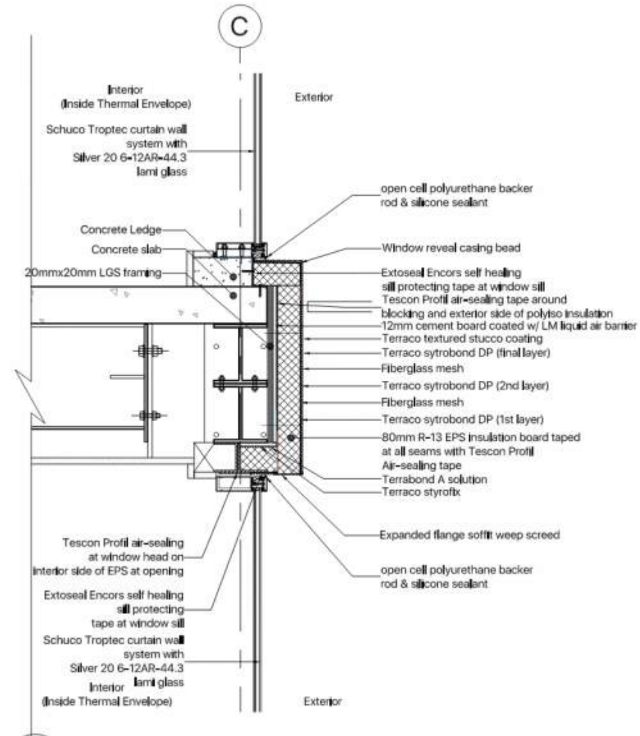


Typical Roof-Wall Detail. Courtesy of Jordan Parnass Digital Architecture (JPDA).

10. Windows and installation of the window

The windows are a double pane curtain wall system with Gutmann F50 thermally broken metal frames. The EIFS system was detailed to wrap under / over the window frame to provide continuity of the thermal insulation plane at the window to wall connection. The thermal performance of the window system components are as follows:

- U-frame = 1.61 W/m^2.K
- U-glazing = 1.20 W/m^2.K
- G-value of glazing = 0.22



2 Typ.Section Through Curtain Wall & Slab

Typical Window Detail. Courtesy of Jordan Parnass Digital Architecture (JPDA).

11. Airtight building envelope

The primary air tight layer at the exterior wall is a fluid applied air barrier membrane applied to a 12mm cement board substrate. At the window to wall connection, a combination of caulk and tape was applied to achieve an air tight connection. Additional air sealing via spray foam was provided at the building’s perimeter where continuous steel purlins penetrated the exterior wall assembly. The metal panel roofing structure with air sealing tape provided at the roof to wall connections acted as the primary air seal at the roof.


Glazing Frame Install

BACKGROUND

The factory building for Star Garments Group Private Limited at the Free Trade Zone is a gut-renovated, two-story, commercial manufacturing building located in Katunayake, Sri Lanka. The project is certifying to the Passive House EnerPHit standard with PHI. Part of the Passive House standard is to air seal the building so that it leaks no more than 0.6 air changes per hour (ACH) at a 50 Pascal induced pressure difference between indoors and outdoors, or 1.0 air changes per hour (ACH) with extra documentation. A blower door test is required to determine whether the target airtightness has been achieved.

TEST SPECIFICATIONS

Referenced Standards and Documents

- Airtightness measurements in Passive Houses – Instructions for carrying out measurements (undated)
- EN13829 Thermal performance of buildings – Determination of air permeability of buildings – Fan pressurization method
- Guidelines for Blower Door Testing of Passive Houses (09/02/2018)

Airtightness Target

- 0.6 ACH50 – air changes per hour at 50 Pascals induced indoor-outdoor pressure difference.
- This translates to a 5,058 CFM50 target for the whole building.
- 1.0 ACH50 – air changes per hour at 50 Pascals induced indoor-outdoor pressure difference.
- This translates into a 8,430 CFM50 target for the whole building.

Building elevation:

- 44.8 feet above sea level

Table 1 – Areas and Volumes of the Building and Apartments

Description	Floor Area (Sq. Ft.)	Enclosure Surface Area (Sq. Ft.)	Volume (Cu. Ft.)
Whole Building	39,553 - TFA	70,230	505,812

Testing Agency

- Steven Winter Associates, Inc. – 61 Washington St. Norwalk, CT 06854

Test Team:

- Primary test team contact: Lois Arena, SWA
- Michael O'Donnell, SWA
- Dylan Martello, SWA

TEST EQUIPMENT

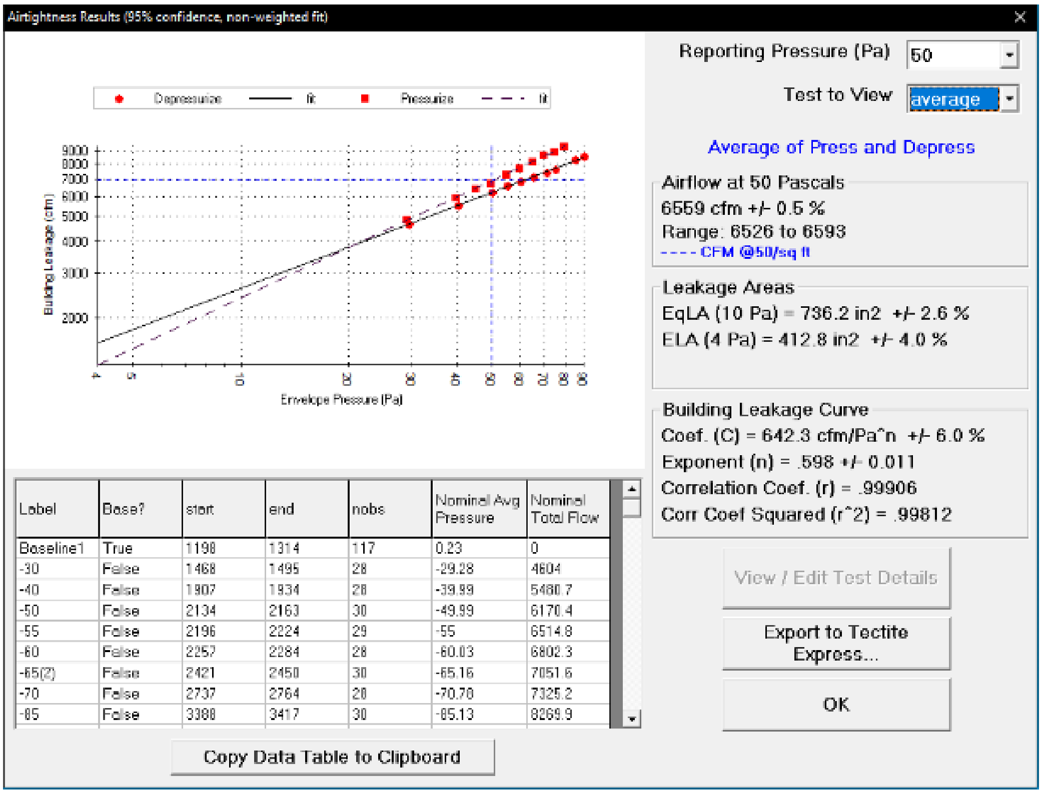
Test equipment manufactured by The Energy Conservatory were used to test the building airtightness. Model 3 test fans were used to induce test pressures across the enclosure. Step down transformers (220-240v to 110-120v) and appropriate fan speed controllers (50 Hz chip) were utilized with the Model 3 test fans. DG-700 manometers were networked using cat5 cables through TECLOG3 software to collect air flow through test fans and air pressure differences between indoors and outdoors. TECLOG3 was used to perform analysis of the data in accordance with EN13829. Test equipment used in this test is listed in Table 2.

Test Condition for Doors, windows, HVAC equipment and HVAC related penetrations:

Per Passive House requirements, the HVAC envelope penetrations are to be sealed during the test, which can be seen applied to items in the list on PDF page 7. The initial air leakage observed was 8,713 CFM under depressurization during building diagnostics.

After extensive air sealing from the initial testing, the final tested average of both depressurized and pressurized was 6,559 CFM50. This translates to roughly 0.78 ACH50 and 0.093 CFM50/sqft enclosure. This result was calculated with <2% margin of error. The correlation coefficient squared was 0.998, rendering ~99% confidence for a near-perfect positive linear relationship between the building leakage and the envelope pressure.

Photo 1:



Below is the extended table of results:

Depressurization

Label	Start Time	Start Pa	End Pa	nobs	End Time	Nominal Avg. Pressure	Nominal Total Flow
Baseline1	9:25	1198	1314	117	9:27	0.23	0
-30		1468	1495	28		-29.28	4604
-40		1907	1934	28		-39.99	5480.7
-50		2134	2163	30		-49.99	6170.4
-55		2196	2224	29		-55	6514.8
-60		2257	2284	28		-60.03	6802.3
-65(2)		2421	2450	30		-65.16	7051.6
-70		2737	2764	28		-70.78	7325.2
-85		3388	3417	30		-85.13	8269.9
-75(3)		3540	3568	29		-75.2	7563.7
-90		3739	3768	30		-90.13	8516.9
Baseline2	10:11	3871	3986	116	10:13	0.05	0
Depressurization: Average @ 50Pa							**6221**

Pressurization

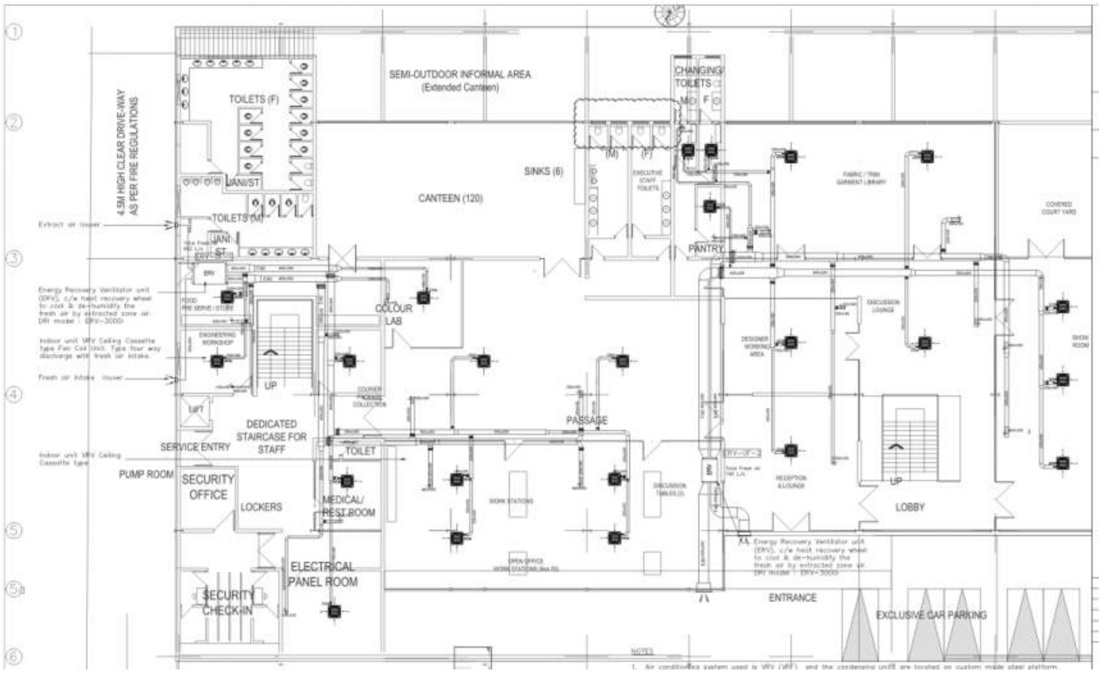
Label	Start Time	Start Pa	End Pa	nobs	End Time	Nominal Avg. Pressure	Nominal Total Flow
Baseline3	10:23	4603	4718	116	10:25	0.43	0
30		5091	5120	30		29.06	4884.6
40		5525	5552	28		39.99	5953.7
45		5595	5624	30		45.12	6417.1
50		5657	5686	30		49.84	6776
55		5709	5738	30		54.97	7335.8
60(2)		5826	5855	30		59.91	7743.3
65(3)		6000	6029	30		65.19	8228.6
70		6218	6245	28		70.06	8757.9
75(2)		6341	6368	28		75.01	9017.5
80		6427	6456	30		80.04	9434.4
Baseline4	10:58	6604	6718	115	11:00	-0.02	0
Pressurization: Average @ 50Pa							**6898**

TOTAL: Average @ 50Pa	**6559**

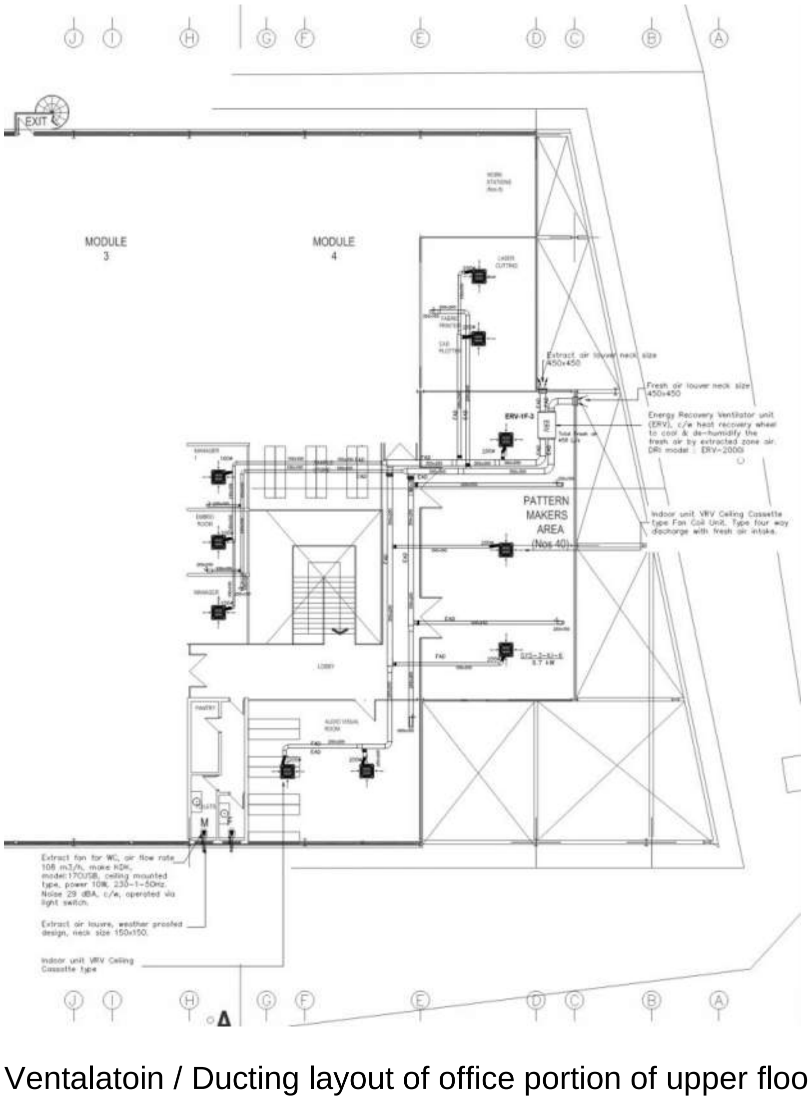
12. Layout of the ventilation system ducting

The ventilation air on the ground floor and a small portion of the upper floor is ducted directly from the ERVs to terminal registers in each interior room. See layouts and screenshot of efficiencies below.

ID	Description	Effective heat recovery efficiency	Energy recovery value η_{ER}	Electric efficiency
	User defined area	%	%	Wh/m³
01ud	Sys 1: DRI - ERV 3000i	72%	70.0%	0.71
02ud	Sys 2: DRI - ERV 3000i	73.1%	71.1%	0.77
03ud	Sys 3: DRI - ERV 2000i	73.1%	71.1%	0.63



Ventalation / Ducting layout of ground floor.

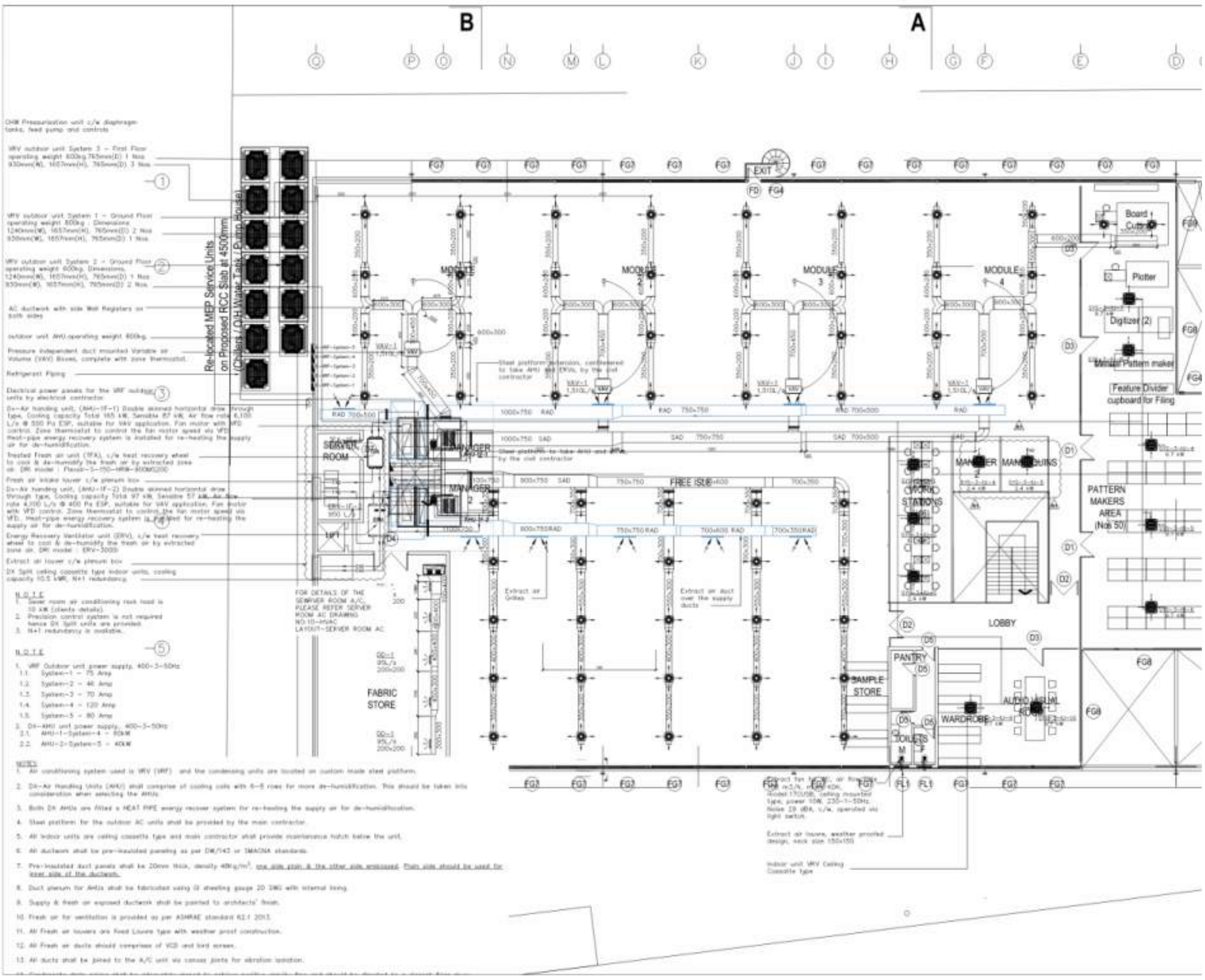


Ventalatoin / Ducting layout of office portion of upper floor.

13. Ventilation unit / central ventilation unit

The ventilation air for the main work area on the upper floor is provided via two ERVs that are ducted into two central air handling units (AHUs) providing cooling and fresh air to the majority of the upper floor. See layout and screenshots of efficiencies below. The two ERVs are supplied by Desiccant Rotors International (DRI).

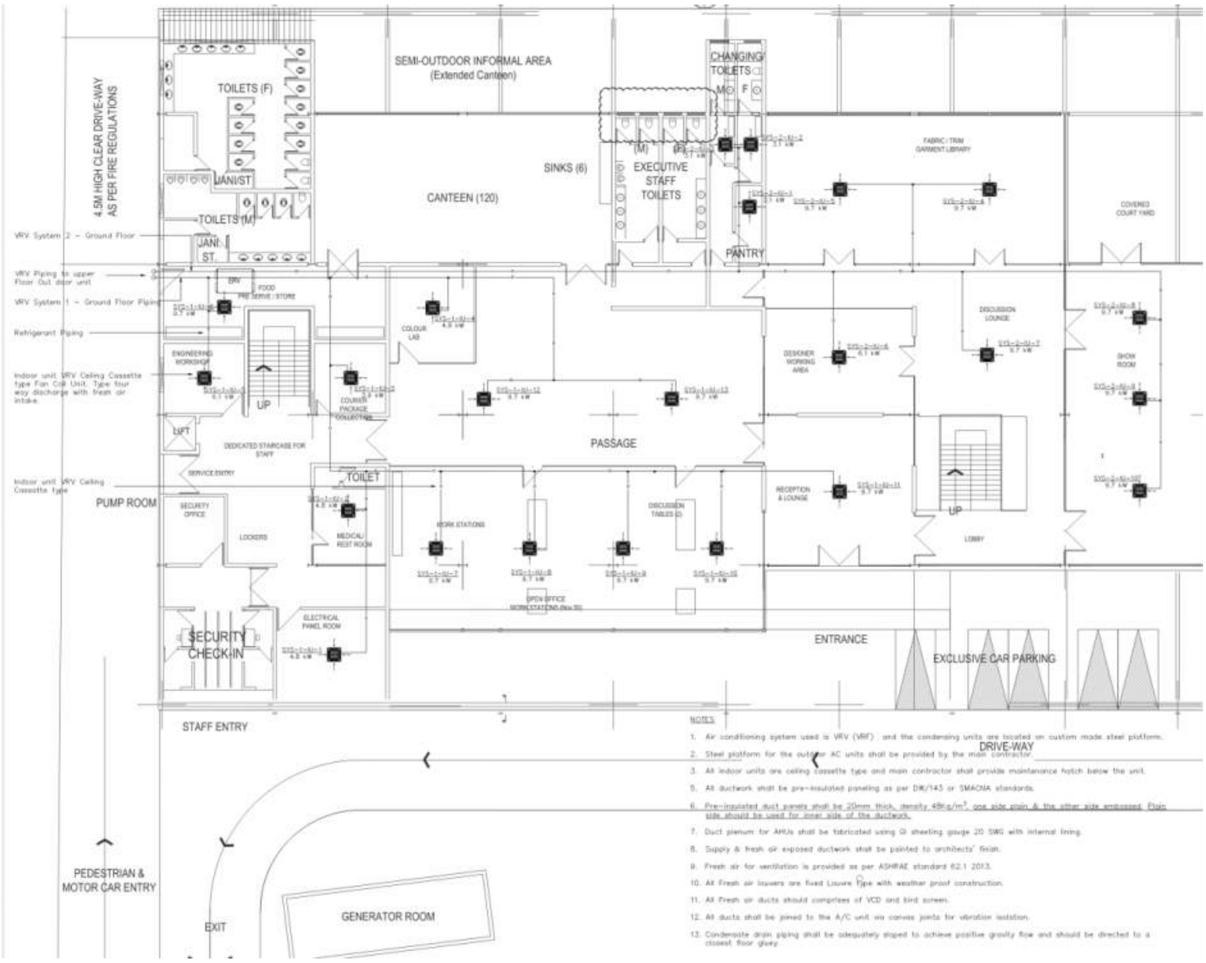
	Recommended specifications to start planning: Frost protection: No requirements; Humidity recovery: Yes	- %		0.45
ID	**Description**	**Effective heat recovery efficiency**	**Energy recovery value η_{ER}**	**Electric efficiency**
	User defined area	%	%	Wh/m³
04ud	**Sys 4: DRI - Flexair-S-150-HRW-900MS200**	**67%**	**61.3%**	**0.54**
05ud	**Sys 5: DRI - ERV 3000i**	**72%**	**70.0%**	**0.87**

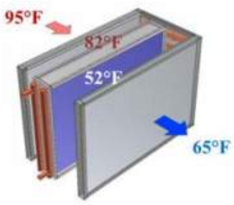


Ventilation / Cooling / Ducting layout of main work area on upper floor.

14. Cooling Supply

Cooling is supplied to the building via a vairable refrigerant flow (VRF) heat pump system. The AHUs for the upper floor have heat pump coils with wrap around heat pipes to passively reheat the supercooled air; this allows for a highly efficient means of enhancing the dehumdification capacity of the cooling system.





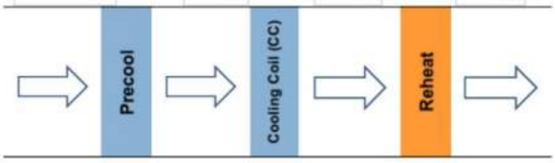
Additional Dehumidification Controls - Heat Pipes w/ Heat Recovery

Air Properties

Air Type:Standard

Elevation: 0ft

	Outside Air	Returned Air	Mixed Air (Standard)	Precool Leaving	Reheat Entering	Reheat Leaving
SCFM	8,683		8,683			
DBT (°F)	79.00		79.00	68.66	54.12	64.52
WBT (°F)	67.82		67.82	64.49	53.84	57.95
RH(%)	56.7		56.7	80.3	98.3	67.8



Coil Performance

	Precool	Cooling Coil (CC)	Reheat
Pressure Drop (in. H2O)	0.21		0.21
Face Velocity (SFPM)	321.60		321.60
Temperature Gain/Loss(°F)	10.30		10.40
Sensible Effectiveness	41.57		41.81
Heat Transferred (BTU/h)	99,142	278,545	99,142
Condensation (lbs/hr)	0.0	128.3	

15. Short Documentation of PHPP-Results (verification sheet)

EnerPHit Verification

Building:	Proposed Factory Building for Star Garments Group Priva		
Street:	Ring Road 2 IPZ		
Postcode/City:	Katunayake		
Province/Country:	Sri Lanka	LK-Sri Lanka	
Building type:	Textile manufacturing & offices		
Climate data set:	ud---01-LK0001a-Colombo Katunayake		
Climate zone:	7: Very hot	Altitude of location:	14.9 m
Home owner / Client:	Star Garment Group		
Street:	P.O. Box 1, Ring Road 2, Phase 1, IPZ		
Postcode/City:	-	Katunayake	
Province/Country:	-	Sri Lanka	

Architecture:	Jordan Parnass Digital Architecture	
Street:	68 Jay St. Suite 501	
Postcode/City:	11201	Brooklyn
Province/Country:	New York	US-United States of America
Energy consultancy:	Steven Winter Associates	
Street:	61 Washington St. Fl 2	
Postcode/City:	6854	Norwalk
Province/Country:	Connecticut	US-United States of America

Mechanical system:	CDC Consultants	
Street:	12/9 Maharagama Road	
Postcode/City:	10300	Makuluduwa
Province/Country:	Piliyandala	Sri Lanka
Certification:	Passive House Institute - Dragos Arnautu	
Street:	Rheinstr. 44/46	
Postcode/City:	64283	
Province/Country:	Darmstadt, Germany	

Year of construction:	2016	Interior temperature winter [°C]:	20.0	Interior temp. summer [°C]:	25.0
No. of dwelling units:	1	Internal heat gains (IHG) heating case [W/m²]:	12.9	IHG cooling case [W/m²]:	12.9
No. of occupants:	546.0	Specific capacity [Wh/K per m² TFA]:	132	Mechanical cooling:	x

Specific building characteristics with reference to the treated floor area

					Criteria	Alternative criteria		Fullfilled?[2]
	Treated floor area	m²	3674.6					
Space heating	Heating demand	kWh/(m²a)	0	≤	-	-		-
	Heating load	W/m²	-	≤	-	-		
Space cooling	Cooling & dehum. demand	kWh/(m²a)	183.0	≤	46	176.0		no
	Cooling load	W/m²	20.52	≤	-	20.83	98.5%	
	Frequency of overheating (> 25 °C)	%	-	≤	-			-
	Frequency excessively high humidity (> 12 g/kg)	%	0	≤	10			yes
Airtightness	Pressurization test result n_{50}	1/h	0.8	≤	1.0			yes
Non-renewable Primary Energy (PE)	PE demand	kWh/(m²a)	344	≤	-			-
Primary Energy Renewable (PER)	PER demand	kWh/(m²a)	164	≤	64	79		no
	Generation of renewable energy	kWh/(m²a)	19	≥	-	22		

[2] Empty field: Data missing; '-': No requirement

Pilot Certificate

Certified retrofit
EnerPHit Pilot Project
(Climate zone: very hot)

Passive House Institute
Dr. Wolfgang Feist
64283 Darmstadt
Germany

Star Innovation Center, Katunayake, Sri Lanka

EnerPHit
Pilot Project
Passive House Institute

Client	Star Garment Group P.O. Box 1, Ring Road 2, Phase 1, IPZ - Katunayake, Sri Lanka
Architect	Jordan Parnass Digital Architecture 68 Jay St. Suite 501 11201 Brooklyn, USA
Building Services	CDC Consultants 12/9 Maharagama Road 10300 Makuluduwa, Sri Lanka
Energy Consultant	Steven Winter Associates 61 Washington St. Fl 2 6854 Norwalk, USA

Buildings retrofitted to the EnerPHit Standard offer excellent thermal comfort and very good air quality all year round. Due to their high energy efficiency, energy costs as well as greenhouse gas emissions are extremely low. The Passive House Institute in Darmstadt has defined the necessary quality standards for EnerPHit retrofits.

The Star Innovation Center is a milestone in industrial energy efficient retrofitting in a tropical monsoon climate. To honour these ground-breaking achievements, the Passive House Institute is hereby awarding the EnerPHit Pilot Project Certification.

Building quality			This building
Heating	Heating demand	[kWh/(m²a)]	0
Cooling	Cooling + dehumidification demand	[kWh/(m²a)]	183
	Cooling load	[W/m²]	21
Airtightness	Pressurization test result (n_{50})	[1/h]	0,8
Renewable primary energy (PER)	PER-demand	[kWh/(m²a)]	164
	Generation (reference to ground area)	[kWh/(m²a)]	19

The associated certification booklet contains more characteristic values for this building.

Darmstadt, 19. October 2018
Certifier: Dragos Arnautu, Passive House Institute

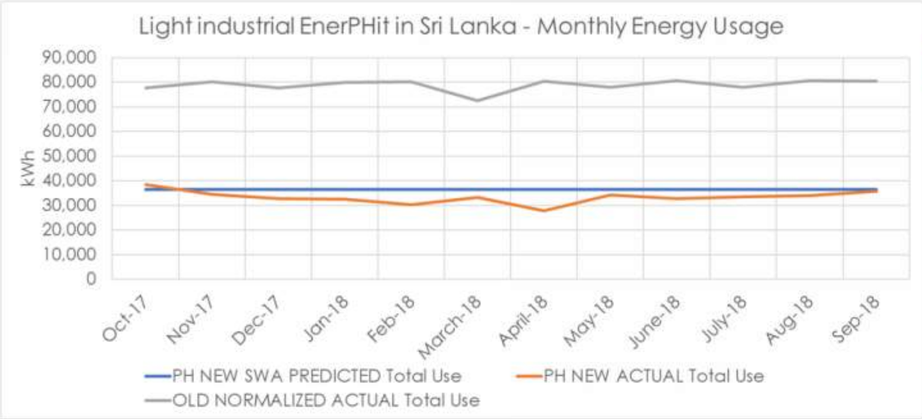
www.passivehouse.com **19134-19170_PHI_EP_20181017_DA**

16. Construction Costs

Building owner does not wish to display this information.

22. User's Experiences

Utility data for the first year of the building's operation was obtained for the project. The project is saving approximately 60% in annual energy consumption and is tracking very closely to the PHPP modelled energy demand. See graph below.



Actual Utility Usage

	Actual % diff. from model
Oct-17	5%
Nov-17	-6%
Dec-17	-10%
Jan-18	-11%
Feb-18	-17%
March-18	-9%
April-18	-24%
May-18	-6%
June-18	-10%
July-18	-8%
Aug-18	-7%
Sep-18	-2%
AVERAGE	**-9%**

23. Available Research Material / Publications

- https://www.youtube.com/watch?v=7ng1TPjN4_M&feature=youtu.be
- https://www.swinter.com/projects/project/star-garment-innovation-center-sri-lankas-first-passive-house/
- http://jpda.net/projects/star-garment-innovation-center
- https://passivehouse-database.org/#d_6030
- Awards
  - AIA New York 2020 Design Award – Sustainability
    AIA New York names 2020 Design Award recipients : NYREJ
  - 2021 Passive House International Award
    Awardees & Finalists (passivehouse.com)