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Assessment of Civil Engineering Department's Buildings, (College of Engineering, Andhra University, Vishakhapatnam, A.P.) as Sustainable/ Green Buildings

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Abstract:

The built environment has a profound impact on our natural environment, economy, health and productivity.

Green Building is a concept of constructing high-performance structures that has no negative impacts on the environment throughout the project's life-cycle. Green building practices can substantially reduce or eliminate negative environmental impacts and improve existing unsustainable design, construction and operational practices.

This study presents a comprehensive perception on the status of the buildings of Department of Civil Engineering at Andhra University in terms of the extent to which these buildings can be considered as green buildings and methods to improve these buildings for better environmental practices.

Key Words: *Green Building Assessment, Sustainability, Green Building Retrofitting*

Introduction:

Green building on college campuses is the purposeful construction of buildings on college campuses that decreases resource usage in both the building process and also the future use of the building. while creating an atmosphere where students can be healthy and more productive.

The construction of green buildings has become a multi-dimensional issue that can be viewed from multiple perspectives. This makes the creation of a suitable evaluation system for green building construction and operations, and how to find the factors that affect the implementation of green building assessment, a difficult but significant subject of study.

Numerous different levels of certification systems have been founded for green building evaluation, owing to different situations in different countries and regions. The primary green building assessment tools used around the world include the (LEED) guidelines developed in the USA, the (BREEAM) system of the UK, and LEED India and (GRIHA) in India.

Objectives:

This study aims to give a complete assessment of the green building performance, in order to achieve the following future goals:

- Improve the buildings performance towards the green buildings' practices

- Get a clean energy and reduce the use of natural resources
- Increasing groundwater recharge through rainwater harvesting
- Obtaining a clean and healthy study environment for students

The process of monitoring and assessment of the buildings was done through some criteria, as the following:

* Energy Efficiency	* Humidity and Temperature
* Natural Ventilation	* Rainwater Harvesting
* Water Quality	* Sanitation

Review of Literature:

Pionke et al. (1990), The explosive population growth has exerted tremendous pressure on the water bodies. The factors such as massive industrialization, rapid urbanization and wide spread applications of various chemicals, pesticides, insecticides, herbicides in the agricultural fields have added considerable number of pollutants to the water resources.

Musa et al. (1994), The high temperature with high humidity increases the transform of heat from the air to the body and at the same time impedes evaporation, which makes the body does not cool quickly and its temperature becomes annoying.

Agarawala and Narian (1997), Answers to our water crisis's may lie in our own water harvesting traditions in the hands of our communities at pretty low cost and small rainwater harvesting systems can play important role in sustainable development.

World Health Organization (2008), There are about 2.6 billion people or 42 per cent of the world's population, lack access to basic sanitation.

Lester R. Brown (2015), Energy is the vital resource for every dimension of the economy. The old economy, fuelled largely by fossil fuels, is being replaced with one powered by solar and wind energy.

Costanzo, V., et al. (2016), The use of renewable energy and the potential to produce it onsite is a very effective green building strategy. Solar is the most common and easily applied renewable energy source on a building site.

Andy Walker (2016), Almost all historic buildings were ventilated naturally, With an increased awareness of the cost and environmental impacts of energy use, natural ventilation has become an increasingly attractive method for reducing energy use and cost and for providing acceptable indoor environmental quality.

ASHRAE Standards (2017), Temperature and relative humidity measurements are often collected as part of an indoor environmental quality investigation because these parameters affect the perception of comfort in an indoor environment.

Verma and Anshu (2019), In the modern day we have started harnessing energy from clean sources like wind, solar, hydro and bio-fuels. Renewable energy is closely associated with sustainable development.

KALAVATI (2023), The provision of safe water and sanitation facilities in schools would be the first step towards a healthy physical learning environment benefiting both learning and health.

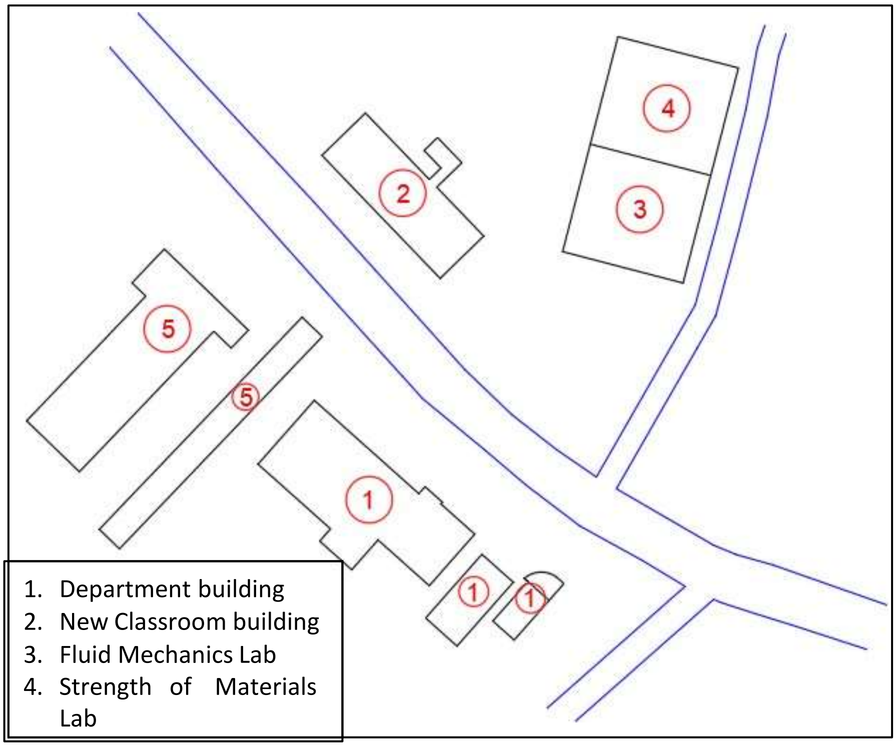
Methodology:

- **Description of buildings:**

The study has carried on the five buildings of Civil Engineering department, College of Engineering Andhra University, at location (17°43'38.5"N, 83°19'12.5"E), those buildings are:

The following figure contains a site plan showing the distribution of buildings, and developed using AutoCAD software

Fig. (1) site plan



1. **Energy efficiency:**

The department building has a combined source of energy that depends on solar energy and power from grid. The solar system of the department building was inspected as follows in order to know its efficiency:

- The number of solar panels and the size of each panel.
- Batteries in terms of battery capacity and total number of batteries
- The inverter which is responsible for converting power from DC to AC

2. Humidity and Temperature:

The (Temperature- Humidity clock (HTC-1)) device is used to take the values of temperature and humidity for each building

- **Temperature-Humidity Index:**

A measure of the reaction of the human body to a combination of heat and humidity, and it can be calculated using the following formula:

$THI = 0.4(T + T_w) + 15$

Where, T is the air temperature measured in the shade, and

Tw is the wet-bulb temperature, the temperature to which the air can be cooled by evaporating water into it at a constant pressure.

THI, T, and Tw are all expressed in degrees Fahrenheit.

The wet-bulb calculator is based on the following formula:

Tw =T* arctan (0.151977(RH%+8.313659)1/2)+ arctan(T+RH%)− arctan(RH%−1.676331)+ 0.00391838(RH%)3/ 2arctan(0.023101RH%) − 4.686035

- T (Temperature)= air temperature or dry-bulb temperature is the temperature given by a thermometer not exposed to direct sunlight.
- RH% (Relative humidity) = a ratio of how much water vapor is in the air to how much it could contain at a given temperature.

Status of Temperature-Humidity Index:

- When the THI is 70 or below, most inactive people are comfortable.
- At THI = 75, about half are uncomfortable.
- When THI = 79, nearly everyone is sweating and uncomfortable.
- As THI rises into the 80s, acute discomfort is common, work efficiency drops, and physical activity should be curtailed.

3. Natural Ventilation:

Measuring the areas of the ventilation openings (windows and doors) and their number, measuring the floor area for each classroom or laboratory were taken, the ratio of the openings to the floor area was calculated and compared to the standards.

The openable area must be at least 15% of the net occupiable floor area. If an opening is covered with louvers or otherwise partially obstructed, calculate the openable area based on the free, unobstructed area.

4. Rainwater Harvesting:

The Catchment area for each building (roof area) was measured then by using the IMD data to find out the annual amount of rainfall, the amount of water that can be collected has been

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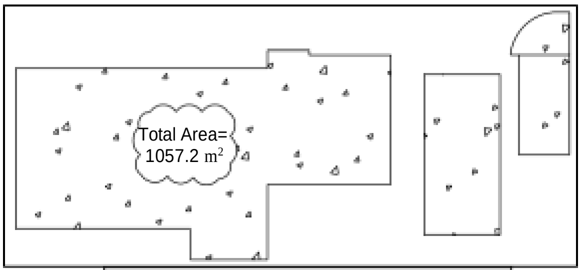
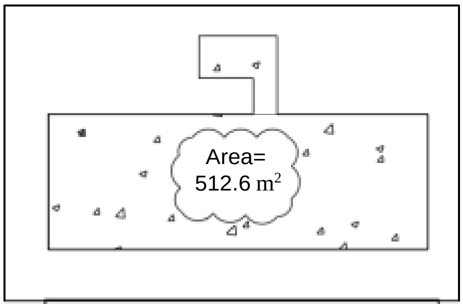
calculated if the rainwater harvesting system is applied in each building. Then designing of Recharge Trench along with recharge well:

The following figure shows the roof or catchment areas of buildings that can be used to rainwater harvesting, Buildings' roofs were modeled using AutoCAD software.

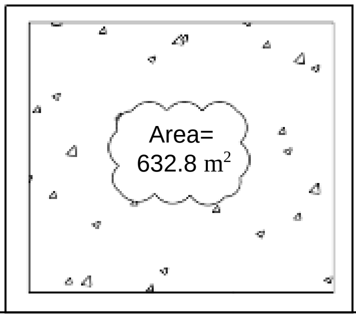
Fig. (2) catchment areas



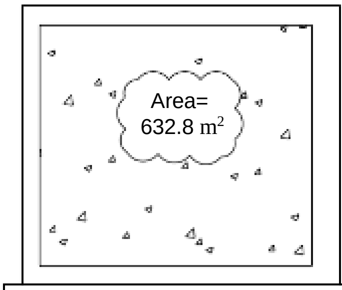
a. Department Building with outgoing buildings



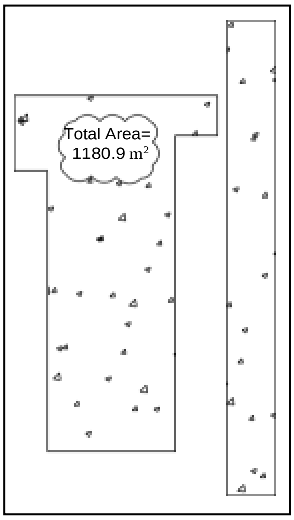
b. New Classrooms Building



c. Fluid Mechanic's Lab.



d. Strength of Materials' Lab



e. Costal Engineering Lab.

Table (1) Precipitation data in Visakhapatnam

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Precipitation (mm)	12	12	17	39	48	103	133	169	160	179	79	4	955
Precipitation (Litres/m²)	12	12	17	39	48	103	133	169	160	179	79	4	955
Number of Wet Days	1	1	1	2	3	7	12	10	12	11	4	1	65
probability of rain on a day	3%	4%	3%	7%	10%	23%	39%	32%	40%	35%	13%	3%	18%

- *From IMD data*

- **Calculation Amount of Rain water from Roof Tops for Recharging:**

The rain water available for groundwater recharging from the roof top catchment can be computed as follows:

$$A \times R \times C$$

Where, A= Roof Top Area

R= Quantum of rainfall

C= Run-off Co-efficient

1. **Trench Design:**

The required capacity of a recharge trench (m^3):

$$\frac{\text{Catchment Area * max Precipitation * Evaporation rate*Run-off Coefficient}}{\text{void ratio}}$$

- for recharge trench:

  Run-off Co. = 0.7 (for Surface pavement)

  void ratio= 0.5 (for commonly used materials like brickbats, pebbles and gravel)

  Evaporation rate: 10 %

5. water quality:

To know the quality of water used in each building, two types of water were studied:

- Drinking water (Treated Water).
- Tap water (Untreated water).

Where a sample of drinking water and a sample of tap water were taken from each building and then analyzed in the laboratory of the department through the following experiments:

* pH
* Total Hardness
* Total Dissolved Solids
* Iron
* Chloride

Then, calculate the values of Water Quality Index (WQI) for each sample and giving the rating for WQI

Table (2) Water Quality Parameters, IS Values, Ideal Values and Weightage Factors of Water Quality Parameters

SI No.	Parameter	BIS Standard Value (Si)	Ideal Value (Vi)	Weightage Factor (Wi)
1	pH	6.5- 8.5	7	0.153
2	Total Hardness (mg/I)	300	0	0.003
3	Total Dissolved Solids (mg/I)	500	0	0.002
4	Iron (mg/l)	0.3	0	3.333
5	Chloride (mg/I)	250	0	0.004

Table (3) Status of Water Quality Based on WQI

SI. No.	Water Quality Index	Status
1	0- 25	Excellent
2	26- 50	Good
3	51- 75	Poor
4	76- 100	Very Poor
5	100 and above	Unsuitable For Drinking (U.F.D)

- *From Water Quality Assessment in Terms of Water Quality Index by Tyagi, Shweta, et al.*

6. Sanitation:

- The sanitary facilities were counted in the buildings of Civil Engineering Department that can be used by male and female students.
- The number of male and female students in the department was 326 Boys and 198 Girls, with a total number of 504 students.
- Sanitary facilities were compared to the number of students, and by knowing the standards of sanitation facilities in educational institutions (displayed in the following table), it was determined whether the number of sanitary facilities were sufficient or not.

Table (4) Standards of Sanitation in Educational Institutions

Fitments	**For Boys**	**For Girls**
Water Closets	1 per 40 students or part thereof	1 per 25 students or part thereof
Ablution taps	1 in each water closet	1 in each water closet
Urinals	1 per 20 students or part thereof	-
Wash basins	1 per 60 *Min* 2	1 per 40 *Min* 2
Drinking water foundations	1 for every 50 students or part thereof	1 for every 50 students or part thereof
Cleaner's sink	1 per floor, *Min*	1 per floor, *Min*

- *From Water Supply and Sanitary Installation by A.C. Panchdhari*

Results and Findings:

1. **Energy Efficiency:**

The Department Building relies on renewable energy (solar energy) to generate a part of the electricity needed for the building.

The solar energy system is often used during the day time, when the loads are light. If the loads in the network increase, the conversion is automatically made to electricity from the grid.

The rest of the buildings depend on non-renewable energy sources or commercial electricity, which comes from fossil fuels and has harmful effects on the environment.

- Details of the solar energy system for the department building:
- 40 solar panels, each with a capacity of 250 w, 8.31 A, 30.12 V
- Inverter with a capacity of 10 KVA

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- 20 batteries each one 12 V, 100 Ah

The solar system produces electricity with a capacity of 10 KVA or 10,000 VA to cover the building's electricity needs with power from grid . The system also contains batteries so that electricity is stored to work during night times or when the sky is overcast, so the efficiency of the panels decreases.

2. Humidity and Temperature:

The values of the Discomfort level in all buildings indicated levels between 81-85, which means: Acute discomfort is common, work efficiency drops, and physical activity should be curtailed. This indicates high temperatures and humidity, as shown in the following table:

Table (5) Temperature- Humidity Index (THI) during Summer Season

	Avg. Temperature (T, ^{0}C)	**Avg. Humidity (%)**	**Avg. wet-bulb temperature (Tw, ^{0}C)**	**Avg. Temperature (T, ^{0}F)**	**Avg. wet-bulb temperature (Tw, ^{0}F)**	**Temperature - Humidity Index (THI, ^{0}F)**
Dep. Building	33.90	43.71	24.51	93.03	76.11	82.65
New Class Rooms	34.75	39.50	24.22	94.55	75.60	83.06
FM Lab	34.38	51.00	26.29	93.88	79.32	84.28
SM Lab	34.54	47.60	25.72	94.17	78.30	83.99
Costal Lab	34.78	46.00	25.60	94.60	78.09	84.08

Table (6) Temperature- Humidity Index (THI) during Winter Season

	Avg. Temperature (T, ⁰C)	Avg. Humidity (%)	Avg. wet-bulb temperature (Tw, ⁰C)	Avg. Temperature (T, ⁰F)	Avg. wet-bulb temperature (Tw, ⁰F)	Temperature - Humidity Index (THI, ⁰F)
Dep. Building	32.10	51.20	24.32	89.78	75.78	81.22
New Class Rooms	33.30	46.00	24.36	91.94	75.85	82.12
FM Lab	32.90	58.50	26.29	91.22	79.32	83.22
SM Lab	33.20	55.10	26.00	91.76	78.80	83.22
Costal Lab	33.30	53.40	25.77	91.94	78.39	83.13

3. Natural Ventilation:

The Opening/floor Ratio was more than 15 % in all rooms, that is mean conforming to the specifications which means that natural ventilation is suitable in buildings.

No proper openings for natural ventilation in costal engineering lab.

Table (7) Opening/floor Ratio for Natural Ventilation

Building	floor Area (m^2)	15% of floor ratio	Total Opening Area (m^2)	Result
Dep. Building	20.42	3.06	5.4372	Ok
New Class Rooms	140.23	21.03	28.53	Ok
FM Lab	523.44	78.52	79.668	Ok
SM Lab	341.04	51.16	58.248	Ok

4. Rainwater Harvesting:

According to Meteorological department, the highest rainfall in single day in Visakhapatnam during the last 10 years is 100.6 mm,

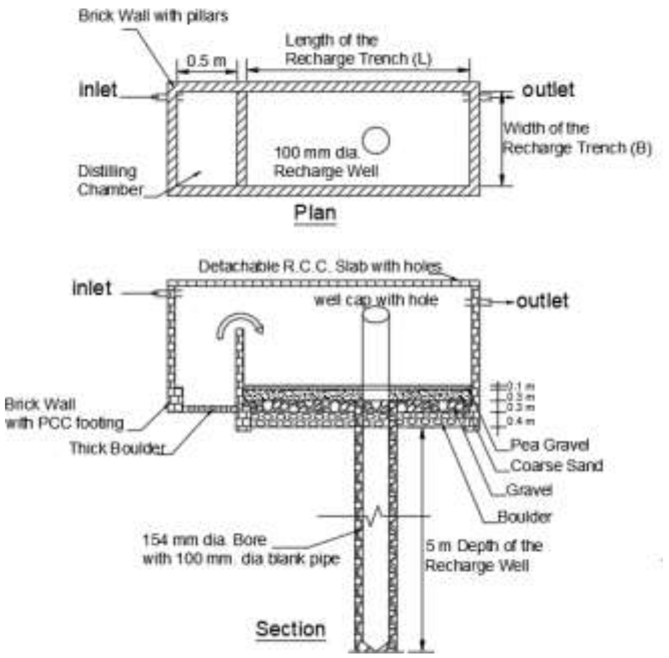
Depth to Water Level in Visakhapatnam varies between 1.23 to 15.78 m bgl, depending on the information from Ministry of Water Resources

Table (8) Rain Water Harvesting

Building	**Catchment Area (Roof Area), m^2**	**required capacity of a recharge trench, m^3/h**	**Trench length, m**
Dep. Building	1057.20	5.58	3.7
New Class Rooms	512.60	2.71	1.8
FM Lab	632.79	6.23	4.2
SM Lab	632.79	3.34	2.2
Costal Eng. Lab	1180.90	3.34	2.2

The length of the recharge trench will be large in some buildings, and the permeable layers may not be suitable in some areas, so design of recharge well is preferable, the following figure illustrate the design of Recharge Trench with a Recharge Well and plotted by AutoCAD software

Fig (3) Recharge Trench with a Recharge Well



5. Water Quality:

The results of the analysis and WQI calculations showed that samples taken from the drinking water had a good result and got values less than 25 (excellent), while the samples taken from tap water got values higher than 65 (poor) in WQI.

Table (9) Distribution of Water Samples

Sample No.	Building
Treated Water Samples:	
1.a	Department Building
2.a	New Class Rooms
3.a	Fluid Mechanics Lab
4.a	Strength of Materials Lab
Untreated Water Samples (Tap Water):	
1.b	Department Building
2.b	New Class Rooms
3.b	Fluid Mechanics Lab
4.b	Strength of Materials Lab
5	Costal Lab

- *There is no treated water (drinking water) in Costal Lab*

Table (10) Results of Laboratory Analysis of Water Samples

Sample No.	pH	Total Hardness, (mg/l)	Total Dissolved Solids, (mg/l)	Iron, (mg/l)	Chloride, (mg/l)
Treated Water Samples:					
1.a	6.5	160	174	0.05	79.43
2.a	6	44	50	0.05	63.54
3.a	6	80	16	0.05	31.77
4.a	6.5	96	28	0.05	39.72
Untreated Water Samples (Tap Water):					
1.b	7.5	400	388	0.2	123.12
2.b	7.5	272	353	0.2	103.26
3.b	7.5	284	286	0.2	99.29
4.b	7.5	312	326	0.2	99.29
5	7.5	160	253	0.2	103.26

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Table (11) Status of Water Quality Index of the Samples

Sample No.	WQI	Status
Treated Water Samples:		
1.a	14.53	Excellent
2.a	13.00	Excellent
3.a	13.00	Excellent
4.a	14.47	Excellent
Untreated Water Samples (Tap Water):		
1.b	65.25	Poor
2.b	65.20	Poor
3.b	65.19	Poor
4.b	65.20	Poor
5	65.15	Poor

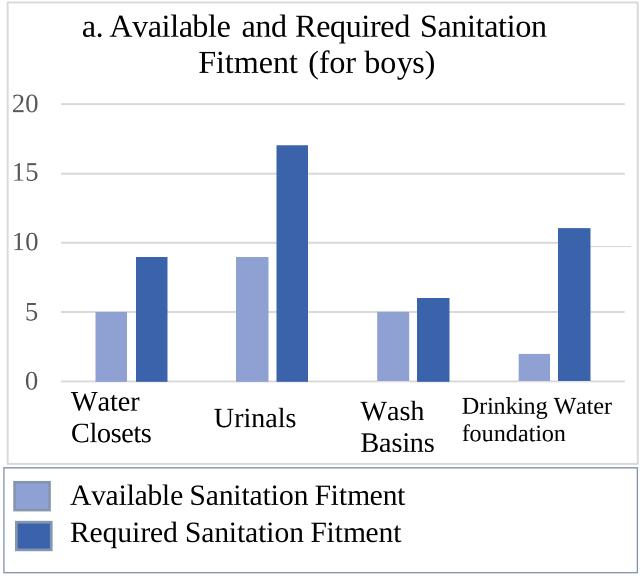
6. Sanitation:

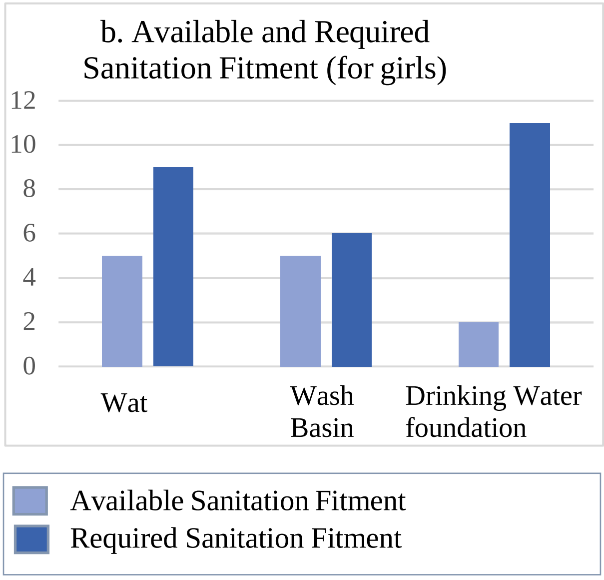
Table (12) Number of Sanitation Fitments for Boys and Girls

	For Boys			**For Girls**		
	Available		**Required**	**Available**		**Required**
Fitments	**Dep. Building**	**New Class Rooms Building**		**Dep. Building**	**New Class Rooms Building**	
Water Closets	2	3	9	2	3	9
Urinals	4	5	17	-	-	-
Wash basins	2	3	6	2	3	6
Drinking water foundations *	1	1	11	1	1	11

- *Drinking Water foundations are the same for both boys and girls in each building*

Fig (4) Comparison of the number of available and required sanitation fitment





Conclusion and Further Development :

Summary and Conclusion:

These buildings are considered traditional buildings, but some buildings showed a good compatibility with green building standards. The buildings differed in terms of what standards were applied in each building, depending on the operational function of each building. By applying some improvements to buildings, building performance can be increased and would become more green building compliant.

- It is possible to expand the use of solar energy systems, supply systems for all buildings, and expand the existing system in the department building, which works in conjunction with commercial electricity that is not environmentally friendly to achieve completely clean energy.
- As expected, the results showed high temperature and humidity values, due to the buildings being affected by the general atmosphere of the city. Solutions can also be followed for more natural ventilation and cooling systems to reduce high temperatures and humidity.
- The sizes of the openings required for natural ventilation and their ratio to the floors' area were very satisfactory.
- Rainwater collection system is designed for each building. There is a wide surface area that can be used and utilized to collect rainwater.
- The results of the analysis of drinking water samples were satisfactory and it was classified as "Excellent" in the Water Quality Index. But for the tap water samples it contained high values of hardness and chloride and it was classified as "Poor" in the Water Quality Index.
- The results showed that there is a shortage in the number of sanitary facilities such as toilets, washing basins and drinking water foundations for both boys and girls so, the sanitary facilities should be increased.

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Suggestions for Further Development:

- **White Roofs:** As a result of the high temperature, white roofing solutions can be applied to reduce the temperature.
- **Rainwater Harvesting:** Models were designed in this study to collect rainwater for groundwater recharge, which can be reliable and developed for future studies
- **Solar Power:** solar energy systems should be established for each building, feasibility studies and measurement for capacity needed by each building should be carried out.
- **Recycling of Graywater:** As greywater contains fewer pathogens than blackwater, it is generally safer to handle and easier to treat and reuse onsite for toilet flushing, landscape or crop irrigation, and other non-potable uses.

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