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Subject: Submission of FINAL Reports on Technical Studies on "Climate Change and Urbanization" Under Research Collaboration between GCISC and NED University of Engineering and Technology, Karachi, duly funded by HEC.

In continuation of the Draft reports submitted on 17th August, 2018, and since no comments are received to date, we are pleased to submit the two Final Reports as attached:

a. Energy Efficiency in Public Transport for City of Karachi, Pakistan

b. A Strategy of Enabling Pakistan's Construction Industry to Climate Friendly Buildings

Prof. Dr. Mir Shabbar Ali

REPORT 2

A Strategy of Enabling Pakistan's Building Industry to Climate Friendly Buildings
A case study of Karachi

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A Strategy of Enabling Pakistan's Building Industry to Climate Friendly Buildings
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NED University of Engineering and Technology

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INTRODUCTION

BACKGROUND

Twenty first century is an era of rapid and continuous exploration. A sizable number of scientific inventions are the major reason of improving lifestyles, communication and facilities but on the other hand the rapid environmental degradation, depletion of resources, irreversible damage to natural habitat is rising due to mal practices. Construction industry is energy and resources intensive sector. At the initial stage of construction to operation and maintenance phase and eventually at the end of building life cycle (dismantling phase) it demands a substantial amount of energy and resources. *Buildings have a lifespan that lasts for 50 to 100 years throughout which they consume energy and emissions. The building sector is a global greenhouse gas emitting sector, is poised to fuel the world's rush towards climate change.* (William, 2007:2)

The primary function of building is to provide shelter and comfort to its users. Parameters of sustainable architecture pave a pathway towards user comfort, efficient use of energy, and successful environmentally friendly design. *One of the major strategies adopted all over the world is the design and construction of energy efficient buildings* (B. Metz, O.R. davidson, P.R. Bosch, R. Dave, L.A, Meyer, 2007). On the contrary, inappropriately mushrooming built structures is the major cause of excessive non-renewable energy consumption. This results in its after effects on the natural, social and economic balance. According to the U.S. Green Building Council (USGBC), *buildings account for an average of 41% of the world's energy use.*

According to international energy agency, Pakistan has a limited contribution in global greenhouse gases emission but, yet it is quite vulnerable to adverse climatic changes. One of the most alarming news in this context was published in Daily Dawn that Nawab shah (Shaheed Benazir Abad) is spotted as the world's hottest place with 50.2 degree Celsius on 30th April 2018. (Dawn, 2^{nd} May 2018).

Moreover, Pakistan is suffering from severe electricity scarcity. There is a gap between demand and supply (WAPDA, 2009). This dire situation heralds an immediate response to curtail the crises with climate responsive architectural and engineering design in build environment. *Energy efficiency in buildings can be achieved through an approach involving adoption of bio-climatic architectural principles responsive to the climate of the particular location: use of materials with low embodied energy, reduction of transportation energy, incorporation of efficient structural design, implementation of energy efficient building systems and effective utilization of renewable energy sources to power the building* (Agarwal, 2004).

OBJECTIVE AND SCOPE OF STUDY

OBJECTIVE

The major objective of this study is to provide a frame work of design parameters, which helps in achieving climate friendly buildings.

1. To analyze the current situation of build environment
2. To analyze the design parameters of existing build environment with reference to user comfort and self-sustenance (Case analysis: Karachi city)
3. Identifying possible design solution

SCOPE

The scope of study has been narrow downed to case analysis of Karachi city. It consists of building analysis of various building types in Karachi city. In depth case studies were carried out, of selected building along with user group feedback, practitioners and expert's response.

This study is formulated to highlight the design parameters, which efficiently responding to climate and hence facilitating its ends user in terms of comfort and expense.

RATIONALE FOR STUDY

The major aim of this study is to outline important climate friendly design parameters in building construction industry. Karachi is largest city of Pakistan, it houses 16 Million people. Generally, buildings in Karachi are not climate responsive. It is clear after the heat wave catastrophe of 2015. Which gulp about 1200 citizen during heat wave attack. Karachi's vulnerability to climate change demands, a complete frame work for climate responsive architecture.

Karachi shares a long coastline on its southern side, which is an important sources of prevailing sea breeze. The pleasant sea breeze, especially during evening and night time should be incorporated in the building design. This study explores certain prevalent design parameters that are working well in the context of Karachi.

SECTION 1

PARAMETERS OF CLIMATE RESPONSIVE ARCHITECTURE

Climate responsive architecture demands a proper usage of passive design strategies along with active energy conservation.

According to Agboola (2011), *Passive design is about taking advantage of natural energy flows to maintain thermal comfort. It is about using the appropriate building orientation, building materials and landscaping. The buildings should be properly oriented, and the fabric of the building envelope should be specified to prevent or minimize heat gain. Shading also should be provided to minimize solar radiation.*

Active energy control comprises of mechanical devices and equipment to create user comfort. It includes fans, artificial lights, pumps, occupancy sensors, HVAC system etc.

Following are the parameters of climate responsive building design

a. Orientation
b. Form of the building
c. Façade Design
d. Cooling Strategies
e. Sustainable Materials

I. ORIENTATION:

Orientation refers to the positioning of the building with consideration of cardinal direction. A climatic responsive building should be oriented to intake maximum wind and diffused sun light.

Well-designed buildings should be oriented, and the spaces arranged in such a way, that most rooms face towards the equator. In this way, the eastern and western sides are exposed to the low-angle summer sun in the morning and afternoon. The high angle of the sun in the sky in summer makes it easy to shade windows using only a generous roof overhang or horizontal shade. The longer north/south sides of the building benefits from the low angle sun in winter. The roof overhang or shading on the equator side should allow the Sun to shine into the building when its warmth is required in winter, and provide adequate protection from high-angle Sun in summer (Aksoy and Inalli 2006)

Sun Orientation:

Shading of the east and west elevations is difficult because of the low sun and may require special devices (awnings, overhangs, blinds); whereas the south and north sides can easily be protected by an overhanging roof. Thus, the best orientation for protection from the sun is along the east-west axis.

Wind Orientation:

Orientation of building according to wind direction helps in controlling prevailing wind according to climatic zone. *Natural ventilation can be achieved in two different ways i.e. cross ventilation and stack ventilation. Cross ventilation works on the principle of inlet and outlet being controlled with the window location and size, while stack effect uses a mechanism of negative and positive pressure. The hot air rises, and cold air settles down with the rise of hot air a negative pressure is developed around the area, to neutralize the pressure difference cold air moves towards the negative pressure thus creating a wind flow. One of a strategy to achieve stack effect in the building is solar chimney coupled with courtyard planning.* (Yaniv,2012)

II. FORM AND MASSING

In architecture, form is the shape or configuration of the building or the visual appearance of the building. Building form is one of the major yardsticks to minimize heat gain in summers and heat loss in winters.

Another important factor related with building form is its massing profile. Massing is the arrangement of building block. It can help in achieving visual and thermal comfort by channelizing or obstructing wind flow and acting as shading device for surrounding buildings. Building block geometry and positioning can affect wind flow and its velocity.

Massing of blocks can help regulate the summer wind and achieve ventilation and obstruct wind flow in winter season. (Pedata,2011). Figure (1) explains some examples of massing to channelize wind flow. [3]

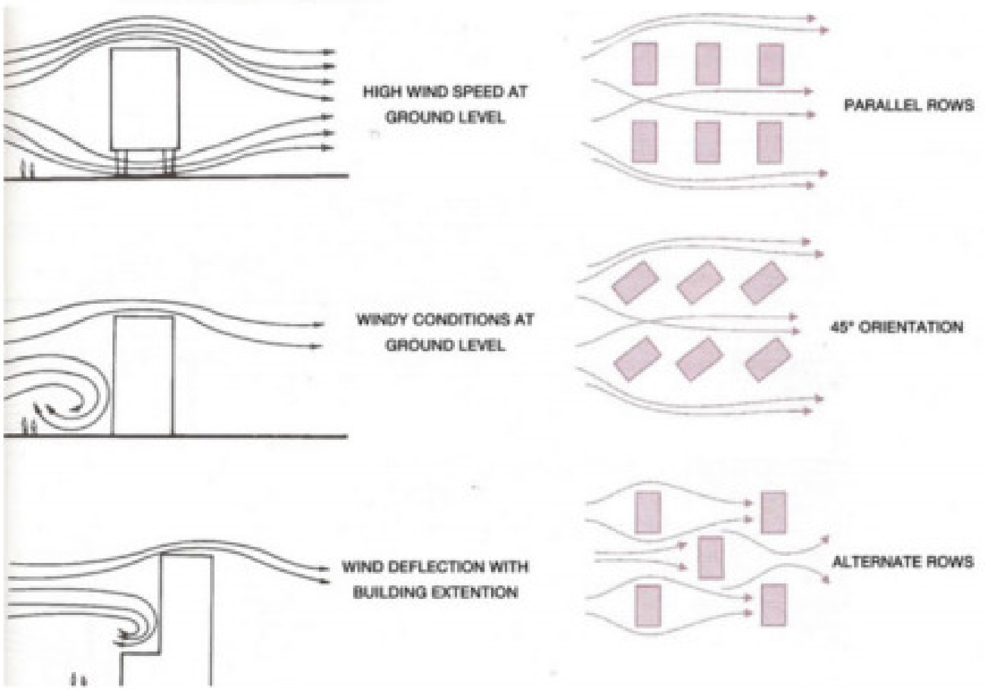


Fig (1) massing influence on wind path (Pedata, 2011)

A form can be further classified with respect to surface to volume ratio, self-shading forms, and courtyard inclusive forms.

- **Surface Area to Volume Ratio**

The surface to volume ratio of a building has a substantial impact on heat gain or loss of the building. The sprawl of surface area is directly proportional to heat gain and loss of building. Hence, compact shapes are preferred in building design to reduce energy loads to warm or cool the indoor spaces.

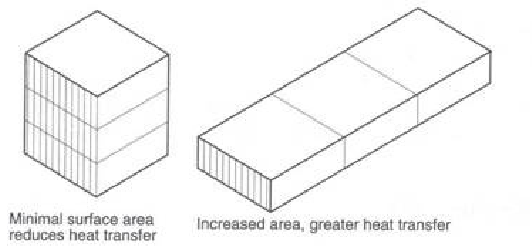


Fig (2) Shows the heat gain or loss via surface compactness

- **Self-Shading façade and shading devices:**

Self-Shading façade is derived from long projecting roofs and over hangs. It is an important tool to prevent direct sunrays and creates a buffer zone for air to cool down.

Shading design devices plays a crucial role in cutting the direct sun glare and achieving diffused day light for visual and thermal comfort of the occupant. Shading device size and type depends on the orientation of the window.

In general, horizontal shading element works well in north and south orientation and vertical fenestration are required to cut sun from east and west. However, the trickiest design of shading is concerning the southwest and southeast orientation. As in these directions the altitude of sun is in the midrange. Hence, only horizontal and only vertical shading device will not cut the glare only a combination of both types of shading is required to cut the harsh sun. (Yaniv, 2012). Fig (3)

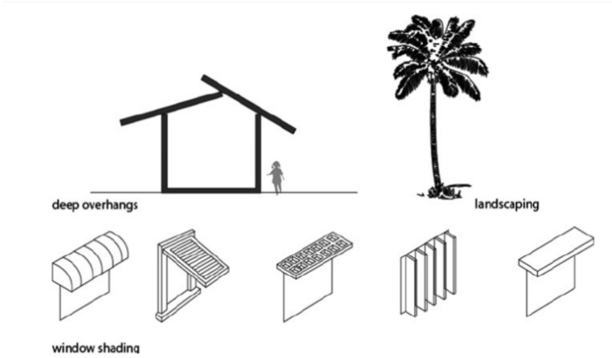


Fig (3) How different openings can affect the design (Yaniv, 2012)

Various software like Eco-Tec, Revit, Sketchup can help in simulating the performance of shading device according to its orientation.

- **Courtyard Forms:**

A court is an open area that is partially or completely enclosed by indoor walls. It works as a light and wind well for the internal areas of building. It has gradually grown from Simple Square, circle or rectangle shape to modified shapes like U-shape, L-shape, T-shape, V-shape, H-shape or Y-shape. *Courtyards have been generally referred to as a microclimate changer, due to their ability to mitigate high temperatures, channel breezes and adjust the degree of humidity* (Saxon, 1986). Fig (4) shows example of a courtyard.

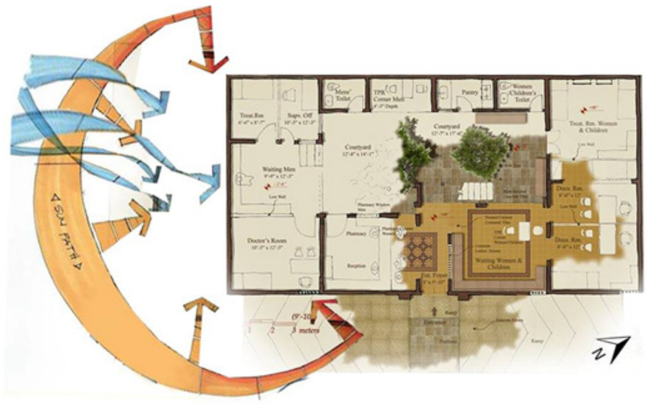


Fig (4) SINA Health and Care Clinic's Courtyard

III. FAÇADE DESIGN

The major constitute of façade design is fenestration, shading devices, wall cladding along with insulation material. The elements of façade design are important with reference to both aesthetics and thermal performance. Appropriately design fenestration elements are the catalyst in building's overall energy conservation, as well as its occupants' well-being, health, comfort, and productivity. Size and proportion of fenestration should be developed according to climatic zone along with strong consideration about u-value, R-value, reflective properties and visual transmission of glass.

An important metric of facade's characteristics is the window-to-wall ratio (WWR). This is the proportion of glazed to opaque facade area. This ratio is a significant contributor to a facade's solar heat gain and energy consumption. In most cases, higher WWR result in greater energy consumption, since thermal resistance of even a well-insulated glazed facade is typically lower than that of an opaque facade. For hot and warm climates, increased WWRs cause cooling loads to increase due to increased solar heat gain. For mixed and colder climates, higher WWRs also affect heating loads, especially for buildings located in cold and very cold climates. In all climate types, reducing the WWR (by increasing the amount of opaque facade relative to glazed facade) improves the energy efficiency. (Ajla Aksamija, 2015)

IV. MATERIALS AND ENERGY EFFICIENCY:

The right choice of material also helps in reducing the energy consumption of buildings and contributes to improve indoor thermal environment. *Not only do buildings use energy to condition spaces (heating and cooling) and provide services (lighting, motors, equipment), but they also represent an investment of in energy in their construction and selection of materials* (ENERCON 1990).

Use of locally available materials reduces energy consumption levels in transportation thus lead to less environmental degradation. *Related to the embodied energy costs are the energy costs of transportation to bring materials to the construction site. Bringing materials great distances by train or truck is not only costly but also wasteful of energy* (ENERCON 1990).

Utilizing locally available, reusable, recyclable or biodegradable materials in building construction can immensely decrease the environmental loads. Material selection according to climatic condition can help in reducing energy consumption.

V. COOLING STRATIGIES

Following are the cooling strategies to enhance building user comfort.

A. Minimizing external gains
B. Maximizing natural cooling systems

A. Minimizing external gains

Reduction in heat gain can be achieve by following measures.

- **Insulation**

Material insulation is one of the pivotal design specifications which helps in preserving energy to heat and cool a building, enhances comfort by reducing interior temperature variability and noise. It can be an additive element to enhance structural strength.

- **Earth Sheltering:**

This is an interesting design strategy to cover up the building envelope with earth (Fig 5). *It utilizes inherent thermal storage capacity and climate control capabilities of stable subterranean soil temperature to achieve thermal comfort in the building* (Kwok and Grondzik , 2007).

Fig (5): Earth sheltering options

- **Colors & Reflection:**

Reflecting the sun ray from the most exposed parts of building envelope is an efficient strategy to control indoor temperature. The choice of color for a building envelope can also help in reducing the heat intake. Different colors have different reflectivity. *According to technical guidelines reflection depends upon the color of the slab; the lighter the color (white), the more it will reflect* (UN-HABITAT 2010). Roof top is the most heat gain, exposed part of building envelope. It needs better reflective quality to curtail the effects of direct sun radiation. *Following are some of the reflective techniques applied to reduce the heat of rooftops; Lime wash, White Enamel paint, Weather shield white paint, OCEVA-MOL chemical, Aerosol Heat reflective paint. It is advised that the surfaces must be cleaned frequently in order to attain maximum efficiency of the technologies. The durability of the reflective surfaces varies the condition of weather and various other factors.* (Ahmed.A,2014)

B. Maximizing natural cooling system

- **Evaporation**

Water has significant evaporation cooling effects. An amalgamation of water bodies with the build structures can make significant change in the micro climate. The most suitable location for water bodies is on the windward side to maximize follow of cooler wind.

- ✓ **Plantation**

Plantation has a huge impact on thermal comfort of a surrounding spaces. Vegetation on the south and west side can help in buffering the direct sun and cooling the prevailing winds. It also plays an important role in shaping a better micro climate for building users.

- ✓ **Natural Ventilation**

Natural ventilation is the phenomenon in which the natural wind flow is controlled and circulated through the built environment within the comfort limits. Natural ventilation can be enhanced with help of right size and location of openings along with shading devices.

SECTION 2

Situation Analysis – Case of Karachi

Introduction

Karachi is the largest city of Pakistan, with a population of 16 million (Pakistan bureau of statistics, 2017). *It is the provincial capital of Sindh, which is covering an area of 3,527 km2. Its topography can be largely divided into two parts, the hilly area in the north and west and an undulating plain and coastal area in the south-east. All these hills are devoid of vegetation and have wide intervening plains, dry river beds and water channels. Karachi has a long coastline in the south.* (Source: The case of Karachi Pakistan, 2003, Arif Hasan, Masooma Mohib). Historically, Karachi is well known for its evening sea breeze and pleasant weather. This quality of city weather, paves a path towards climate responsive architecture.

Climate of Karachi

Karachi has a moderately temperate climate with a generally high relative humidity that varies from 58 percent in December (the dried month) to 85 percent in August (the wettest month). Unfortunately, temperature of Karachi is rising due to certain anthropogenic activities. *The temperature in Karachi during the last five years has increased by five degrees centigrade* (DAWN April 5, 2018).

The wind in Karachi is more than half the year, including the monsoons blow south-west to west. A cool evening breeze is great boon to inhabitants. The wind in winter changes to east and north maintaining an average temperature of about 21 C. the hottest months are May and June when the mean maximum temperature reaches 35 C. January is the coolest month of the year. During the rainy season in July and August, it remains cloudy almost every day with generally scanty rainfall. However, there are surprising variations from year to year. The average annual rainfall is 56 mm, but in certain years rainfall is higher and may rain heavily within a short span of 48 hours. (Source: The case of Karachi Pakistan, 2003, Arif Hasan, Masooma Mohib)

Urban Heat Island Effect

According to United Nations Environment Protection Agency, 2017 the Urban Heat Island Effect is *"City or Metropolitan area that is significantly warmer than its surrounding natural areas due to certain anthropogenic activities"*.

Urban heat island effect works as a catalyst to increase water and electricity demand, and expenditure on heat related sickness and cure. Additionally, due to increased air-conditioning demand it gives rise to emission of greenhouse gases.

A possibility of occurrence of urban heat island effect was mentioned in *Karachi city climate change adaptation strategy – A roadmap by Farhan Anwar, 2011.* Now it is a ground reality that Karachi witnessed sizable number of heat waves. The June 2015 heat wave has turned out to be one of the deadliest, with death tolls of over 1,200 citizens.

It can safely have deduced that rapid urbanization along with impact of global warming has triggered the UHI effect in Karachi (Hanif, U, 2017). The massive urban sprawl and recurrent heat waves needs a proper mitigation on various domains including climate friendly and less energy consuming build environment.

Building Case-Analysis

Selection Criteria of Case Studies

Buildings affect the climate by their presence, process of construction and use. In Pakistan more than 50% of energy is consumed by the building industry. This energy can be conserved through sustainable land use planning, efficient design interventions, appropriate material selection and use of renewable and alternative sources of energy. In order to implement this energy conservation model, the existing challenges are needed to be addressed and tackled accordingly.

Building sectors in Karachi ranging from residential (single unit, apartments), commercial, cooperate sector, educational institutions and health care centers follow different patterns and factors in terms of their land use, design parameters, energy consumption, and operation/maintenance. About seven case studies are selected from aforementioned sectors in Karachi while keeping in mind the general impression and professional judgment in terms of using energy efficient means for achieving thermal comfort. These sustainable design parameters include:

- ✓ **Form**

Most of the selected case studies have compact form with court yard in the center offering self-shading.

- ✓ **Orientation**

Orientation is considered an important aspect in sustainable design. All the selected case studies are oriented to optimize energy efficiency.

- ✓ **Day lighting**

Selected buildings are well lit during day time lead towards energy conservation.

- ✓ **Cooling Strategies**

Selected case studies have utilized different strategies to combat the summer sun which include solar control (glazed windows, shading devices), minimize external gains (insulation, thermal inertia, reflection), cross ventilation and natural cooling system (evaporation, plantation).

- ✓ **Sustainable Materials**

Most of the case studies have employed locally available materials (having less embodied energy), renewable materials and recyclable/reusable materials (in case of Sina Clinic).

- ✓ **Indoor Environmental Quality**

It addresses indoor air quality and thermal, visual, and acoustic comfort. The selected case studies are found to be thermally and visually comfortable.

List of selected building

1. Farhan Mosque
2. Sina Health Care Unit
3. Visual Studies Department (Student Teacher centre), University of Karachi
4. GPO Building
5. OPP RTI
6. KMC, Soldiers Bazar Market
7. Mega Tower-G4

Introductory Matrix of Case Studies




01	02	03	04
Farhan Mosque Building Typology: Mosque Architect: **Misbah Najmi** Key Features: Earth sheltered building, Passive cooling strategies, U shape Courtyard, Skylight , Wind catchers, Water recycling, Local materials	**Sina Health & Care Clinic** Building Typology: Health Care Architect: **Taimoor Khan Mumtaz** Key Features: Courtyard, Local and recycled materials, Large openings, High ceiling, Overhangs	**STC - Visual Studies Department** Building Typology: Educational Architect: **Michel Ecochard** Key Features: Perforated wall, Sun Breakers - Brise soleil, Louvers, Landscape, Local materials, High Ceiling, Water body.	**GPO Building, Karachi** Building Typology: Office Architect: **M. A. Ahed**. Key Features: Courtyard, Open plan, Openings, Vegetation, Louvers,



05	06	07
OPP-RTI **Building Typology**: Research & Training Institute **Architect:** OPP Architects team **Key Features:** Courtyard, Adjustable Louvers, Cross ventilation, Water efficiency, Wind catchers, Local materials, Vegetation	**KMC Market** **Building Typology**: Grocery Store **Architect:** KMC Architects **Key Features:** Courtyard, Roshan dans, Mashrabiyas, Vegetation, large and small openings, local materials	**Mega Tower G4** **Building Typology**: Office **Architect**: Habib Fida Ali **Key Features:** Raised Floor, Under Floor Air conditioning, water efficiency, CO_2 sensors, occupancy sensors, Insulated envelope

FARHAN MOSQUE

I. ORIENTATION

The Farhan mosque is few degrees deflected towards east. This helps in orienting it to the qibla direction. Due to its orientation, the southern side of the courtyard receives constant sunlight, and the north side stays in shade for most of the day. The most heated west part of the mosque is insulated by the visual roof garden. Figure (6) shows orientation of Farhan Mosque.

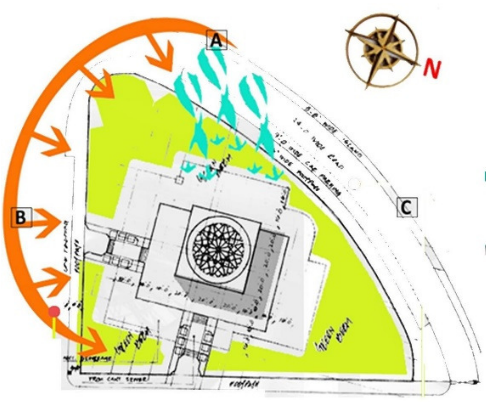


Fig (6) Orientation of Farhan Mosque

According to Architect Ahsan Najmi, Son of Architect Misbah Najmi *"The artificial hill creates a sound barrier so that at all times, the traffic noise is filtered through"* He also explains the usefulness of local and cost-effective materials like stone. *"The stone and the materials used are all local and hence cost-effective. The materials also serve as insulators because of which the stone stays cold for a certain time period when washed with water,"* He explains importance of context with reference to light, air and green spaces. He spreads light on change of micro climate due to greenery and sunken courtyard. *"Wind flows up the hill and the sprinklers bring down the temperature before one gets to the open prayer spaces. The sunken courtyards also create a micro-climate within the prayer space"*

An Interview of Ar. Ahsan Najmi by Shahid Husain, The News, 2009

II. FORM

- **Courtyard**

The main prayer area is surrounded by a courtyard from three sides except from west side, which is creating the qibla wall Fig (7). This prayer area is articulated with three glass doors to allow wind and natural light inside the prayer area. Moreover, the central courtyard creates a suction effect for the wind coming from the south west direction.

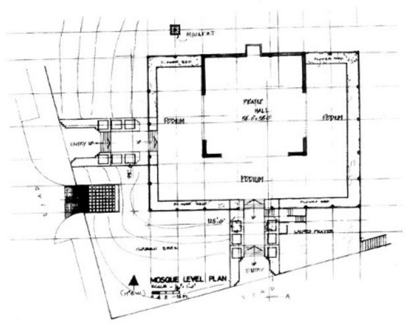


Fig (7) Main prayer hall enclosed within U shaped Courtyard

III. COOLING STRATEGIES

- **Ventilation**

Faran mosque have a very effective ventilation system Fig (8). Despite being in the middle of busy roads, the courtyard and the interior prayer hall have moderate temperature. Even the parking in the basement is quite well ventilated due to the wind catchers and vegetation on the slope.

Fig (8) Air circulation

- **Wind Catchers:**

Small wind catchers see fig (9) are provided on roof garden which works as an inlet of fresh air to the basement and drive out internal air. These wind catchers are quite effective that sometimes the basement is also used for the praying purpose fig (10).

Fig (9) Wind Catchers

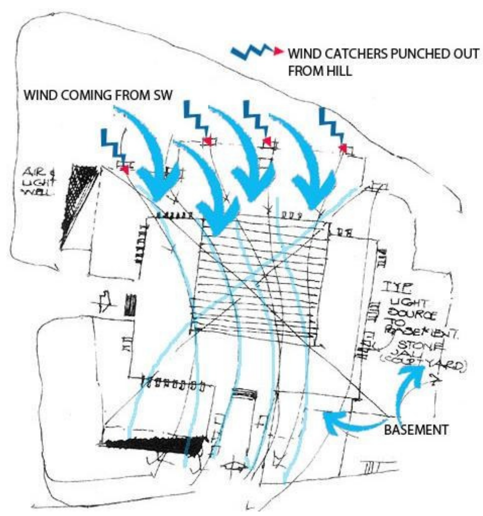


Fig (10) Sketch of wind patterns

- **Microclimate**

The vegetation on the roof garden helps in creating comfortable micro climate, see fig (11). A system of water sprinkler is installed on roof garden. Once the watering of grassy roof top gets completed during day time. Then it started to facilitate court yards with cooler air.

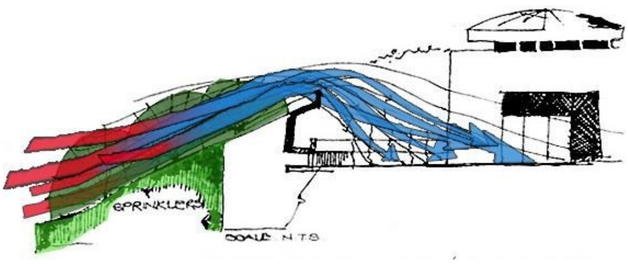


Fig (11) Change in temperature

IV. **FAÇADE DESIGN**

- **Insulation**

Noise protection is one of the main elements in mosques design to provide a noise free environment for prayers. In Farhan mosque a unique design strategy of producing artificial grassy hill has done tremendous work as noise and heat buffer zone, see fig (12).

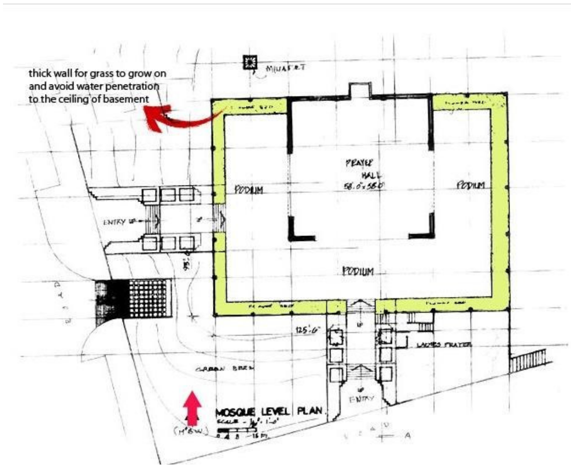


Fig (12) Insulating Envelope

- **Building Envelope Thickness:**

The extended thickness of roof slab up to 10 inches is intentionally designed to allow grass to grow without water penetration into the ceiling of basement. This thick roof slab provides insulation against heat. See fig (12.1).

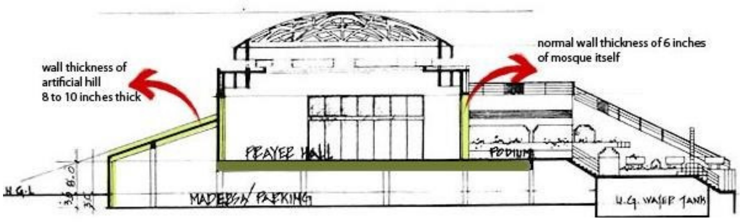


Fig (12.1) Sectional diagram showing wall thicknesses

- **Skylight & Ceiling Height**

The additive height of the dome helps to vacuum out the hot air, which helps in achieving thermal comfort. The high ceiling height and tinted glass dome is also providing more diffused light to prayer area. Basement parking area is equipped with ventilators to enter light, see fig (13).

Fig (13) High ceiling and light inlets in parking area

V. MATERIALS

The structural system of mosque is RCC with external cladding of locally available stone. This stone cladding helps in insulating the building envelope, fig (14). The central courtyard is cladded with Jhelum mountain stone. This stone type has good water absorption capacity from air. During the day time it produces evaporative cooling effect.

Fig (14) Exterior stone Finish

VI. VEGETATION

Vegetation is an interesting aesthetical element in Farhan Mosque design. It plays an important role in providing better microclimate and acoustical control to Mosque. The Pindos palm and bushes are also planted on green roof. These trees are densely located on the west side of the building to provide shade from the west sun to the main prayer hall, fig (15).

In winters, it blocks the cold winds and keeps the environment thermally comfortable without any use of heating devices.

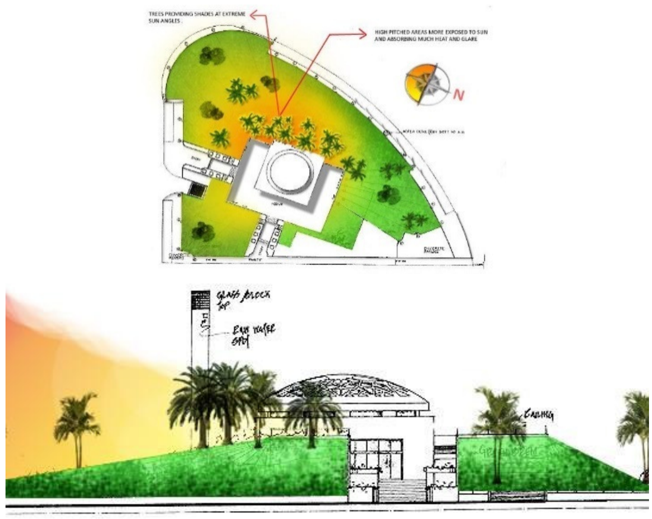


Fig (15) Vegetation around the mosque

VII. WATER RECYCLYING

An efficient system of water conservation of ablution water is incorporated in the mosque. The water drained out from the ablution area is collected in storage tanks for further supply to water sprinklers, installed on roof garden, fig (16).

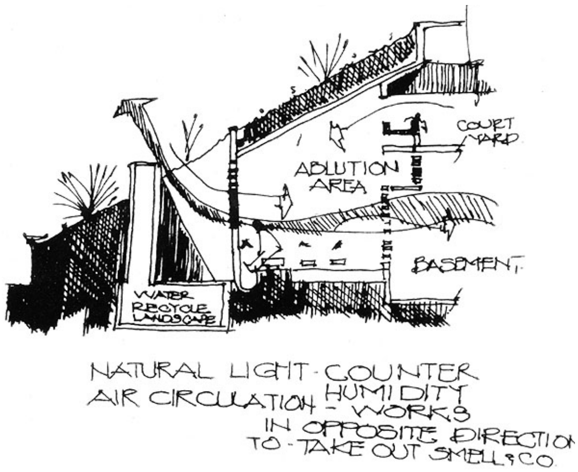


Fig (16) Water Recycling

SINA HEALTH & CARE CLINIC

SINA Health, Education & Welfare Trust is a privately funded not-for-profit-organization that provides primary healthcare services to underprivileged people.

This trust consists of 17 clinics, 2 referral clinics and 1 mobile unit. Overall, it caters to the needs of more than 500,000 individuals annually.

Their clinics are in densely populated urban slums to provide accessibility to most deserving people.

According to Architect Taimur Khan Mumtaz, designer of Sina Clinic "*Karachi's Maritime/Coastal Hot-Humid Climate requires a low thermal-capacity structure (due to the small diurnal – day/night temperature differential) which should be coupled with shade and cross- ventilation. The image of a tree is a perfect illustration of the climatic design principles appropriate for Karachi*". With respect to orientation of Sina Clinic he further explains "*Orientation is important while considering wind movement and shading. The building /site is longitudinally orientated on the North-South Axis with a Courtyard in the middle. It was proposed to have high level openings (these would also bring in light) on the windward side of the building with openings diagonally across from this at body height to facilitate cross-ventilation*". In terms of effectiveness of locally available materials he elaborates "*Local materials are often cost-effective and appropriate hence the choice of Portland Cement, concrete and sand was logical for Karachi in the case of Sina's remodeling projects. Thus all finishing materials and elements are Portland Cement based, either as colour-crete or custom-designed molded colored/terrazzo concrete elements. These include mold-&-cast modular concrete Lattice Screens/Jalis and Dados*". He also explains in detail the finishing materials that are used in interior and exterior spaces. "*For floors and interior dados appropriate colored, already available cement or concrete tiles are used: Pressed-Cement colored tiles for interior floors; Concrete Pavers for exterior floors; Matt-finished Cement/Concrete Tiles for interior courts; and Terrazzo Tiles for interior dados*".

An interview with Taimur Khan Mumtaz (August 2018)

I. ORIENTATION

This clinic is in the Shireen Jinnah Colony, Clifton Block-5. The low-income settlement surrounds the clinic with street width of 5 feet on east side and 10 feet on southern side. The northern and western side of building is attached with surrounding residences of two to three story units. The clinic longer axis is oriented towards east – south direction, fig (18).

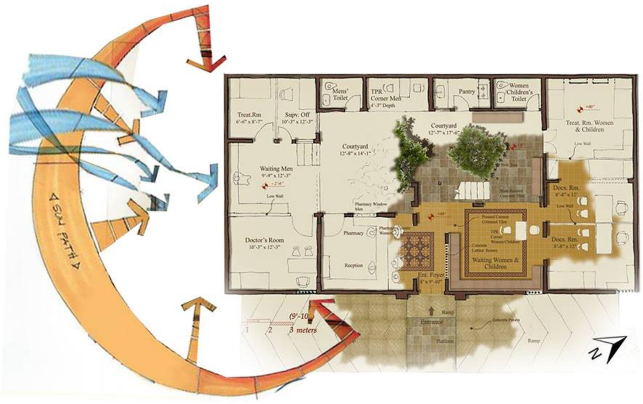


Fig (18) Orientation of the clinic

II. FORM

- **Courtyard:**

The building has external openings on the South-western and South Eastern side, with road width of 10’ and 5’ respectively.

To provide natural light and ventilation, a central court yard is incorporated in design, fig (19). The arrangements of rooms around the courtyard helps in providing natural light and wind to the North eastern side and north western side.

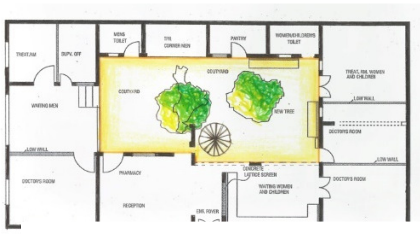


Fig (19) Central courtyard in the Sina Clinic

III. COOLING STRATEGIES

- **Large Openings:**

The building has large external openings as an inlet of wind and daylight, fig (20). This is further complimented by the internal opening facing the courtyard.

Fig (20) Wind circulation through large openings

- **Stack Ventilation Effect**

The phenomenon of stack effect is taking place due to difference in heights, fig (21). This helps in evacuating the hot air upwards and gives room to dense cooler air to stay in indoor spaces.

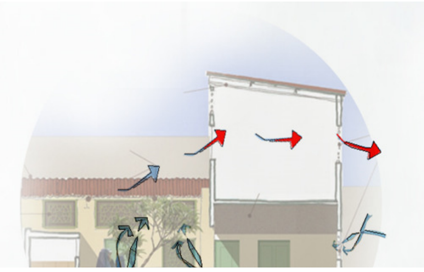


Fig (21) Air circulation pattern through stack effect

- **The Suction Effect:**

During summer season, the courtyard works as suction well to bring in the cooler air inside the surrounding rooms while the indoor hot air evacuates through high ventilators., see fig (22).

Fig (22) Suction Effect

- **Ceiling Height and Wall Thickness**

Various ceiling heights on the ground floor level helps create the stack effect and allows ample inlet of light, fig (22.1 & 23). The structure is overall a load bearing structure with wall thickness of 6"

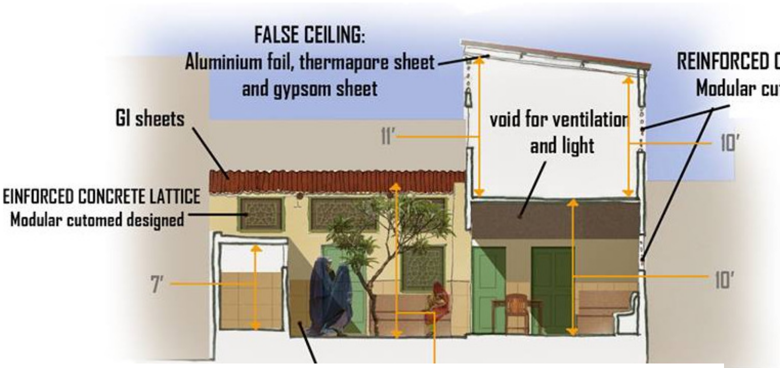


Fig ((23) Section showing wall thickness and different ceiling heights

Fig (22.1) Ventilation through wall openings

- **Vegetation**

The court is embraced with trees, which helps in creating a soothing micro climate., see fig (24).

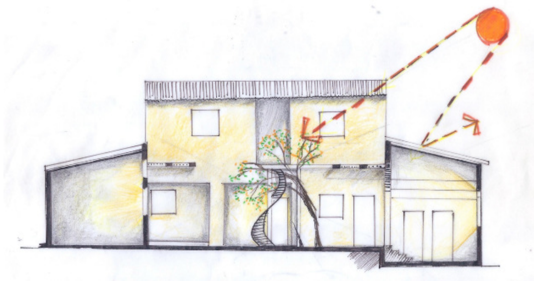



Fig (24) Tree inside the courtyard contributing to microclimate

- **Sun shades -Creation of Veranda**

The Architect has created a verandah space in the courtyard from locally available bamboos, fig (25).


Fig (25) Bamboo Overhangs providing shade in the courtyard

- **Insulation**

During summer, the peak sun is blocked by the insulated angle roofs. A false ceiling is created with the help of 2” thermo pore sheet cladded with aluminum foil on gypsum board false ceiling.

IV. MATERIALS

Architect of Sina clinic preferred to use locally available material like concrete terrazzo tile, pressed concrete color tiles, reinforce concrete lattice, G.I Sheets. These materials are cost effective, durable & require low maintenance. Fig (26) shows various materials used.

Fig (26) M

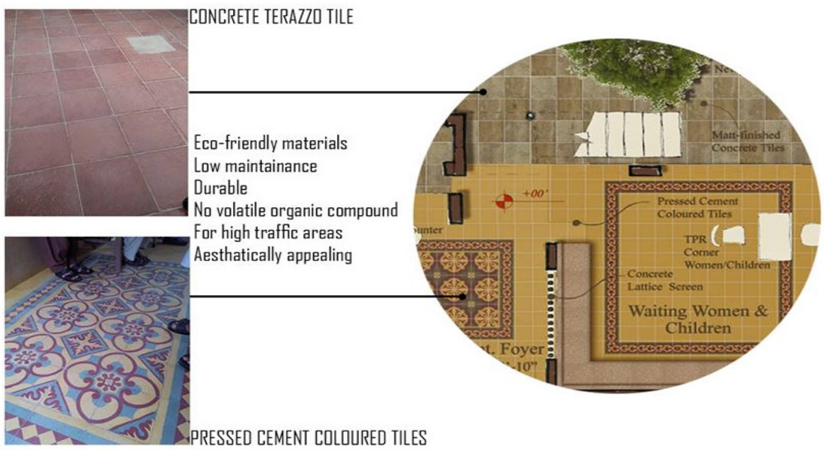


Fig (26) Material Details

STUDENT TEACHER CENTRE - DEPARTMENT OF VISUAL STUDIES (KARACHI UNIVERSITY*)*

A truly site-responding architectural master piece by French Architect Michel Ecochard.

Ar. Mariam Karrar and Ar. Shabbir Kazimi explains the design philosophy of Ecochard *"The comfort and favourable working conditions of the campus residents require protection against the unpleasant tropical climate. This protection will lead to a systematic orientation of the buildings facing the wind, and to a rational protection against the sun rays".* He proposed innovative solutions both at the master plan level as well as building design level. With reference to passive design strategies they explain "*The passive wind and solar design strategies were intended to create a micro-climate within the University campus. The buildings are designed with cross-ventilation approach, oriented perpendicular to the wind direction. The design of tall ceilings and operable windows circulates fresh air and diffuses natural light, in addition to special shading mechanisms called Brisesoleil which helps cool the interior spaces"*. About the importance of orientation they elaborate "*All the buildings designed by Ecochard at Karachi University campus are oriented perpendicular to the wind, (except the laboratories) to maximize cross ventilation inside the building. Ecochard uses the friendliest natural element, the sea breeze which is 245 angle degrees from true North all year round, except month of mid December to mid January".*

An interview with Ecochard building Researchers, Ar. Mariam Karrar and Ar. Shabbir Kazimi

I. ORIENTATION:

The longer dimension of building is oriented along south west axis. This orientation allows direct entry of prevailing winds, blowing from south-west axis, fig (27).

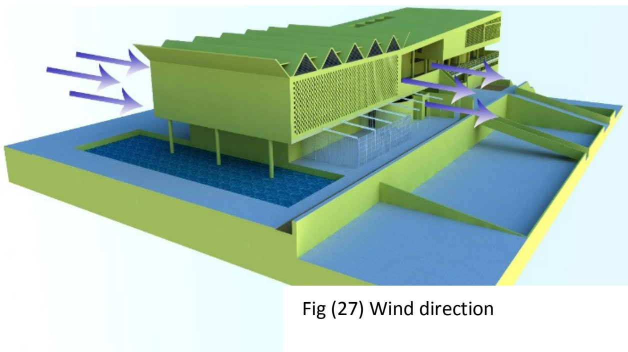


Fig (27) Wind direction

- **Natural Light:**

The main source of diffuse light is large windows along with sunshade device known as sun breaker or brise soleil. Another source of light is massive clearstory window assembled in the main hall. These clerestory windows are also working as hot air evacuator.

COOLING STRATEGIES

- **Landscaping and water bodies**

The building is equipped with land scaping as shown in Fig (28) and water bodies. This is the pivotal important feature to improve micro climate and user comfort in indoor spaces.

Fig (28) water body and vegetation

- **Perforated Walls:**

There are perforated walls on east and west sides of the elevation, fig (29), which serves as a source of good cross-ventilation and diffused light penetration into the indoor spaces.

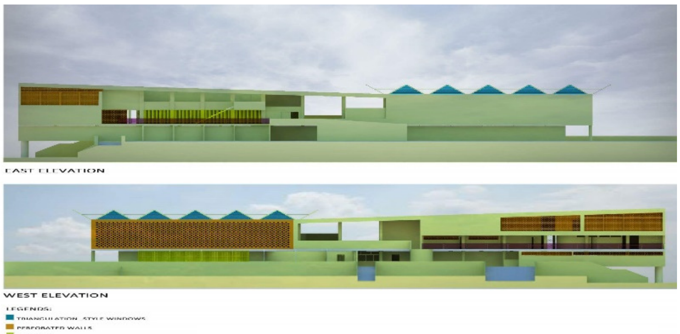


Fig (29) Perforated wall

- **Ceiling Heights:**

The building has varying heights from 10ft-20ft,fig (30). This configuration is systematically designed with high clearstory windows to evacuate warm air from indoor spaces. Moreover, spaces like corridors have nominal ceiling height. This interplay of varying heights creates an ambiance of rhythmic geometry of various connecting blocks of the building.

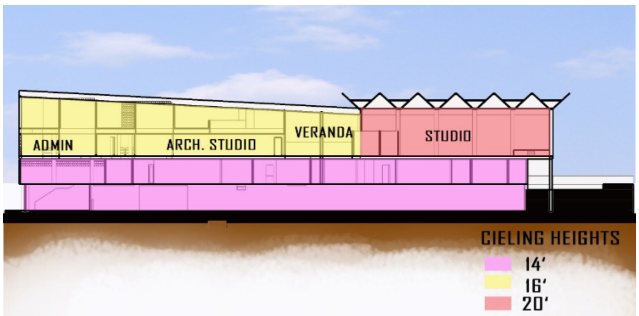


Fig (30) Height variations

- **Self-shading façade/Sunshades:**

The building design is an efficient example of self-shading recessed form along with sun breakers, louvered or perforated walls. This protects habitable spaces from direct weather effects.

GENERAL POST OFFICE - GPO BUILDING

I. ORIENTATION

The main entrance to GPO building is located on the west side. It is facing 60 feet wide I.I. Chundrigar road on its southern side and attached with the Postal Life Insurance building on the northern side. The building is oriented towards western side, which allows maximum air flow within the building and uses natural light adequately to light up the internal spaces, fig (31).

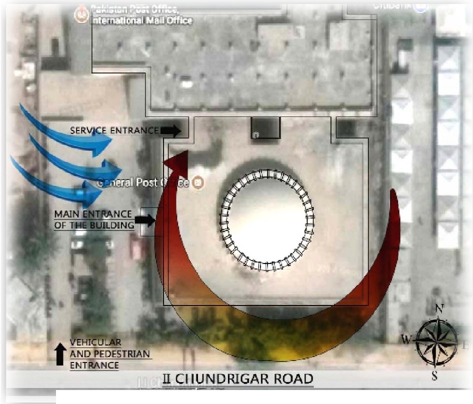


Fig (31) Orientation of GPO Building

- **DayLighting:**

The working places are arranged around a central hexagonal atrium and all four side facades have windows in continuity, it helps to provide natural light to all work places.
The dome above the central atrium has small windows in its drum, which also help to light the central atrium. Sun shading devices are also placed throughout these ribbon windows on dome which breaks the sun angle and allows the indirect light into the central atrium, fig (32).

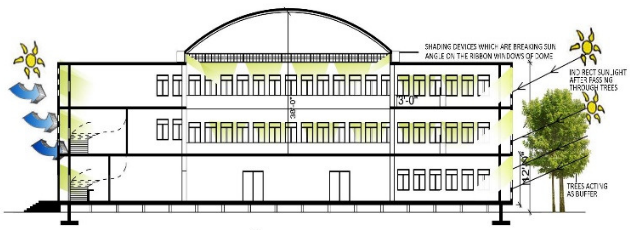


Fig (32) Light and wind inlets

According to our field survey, staff and visitors are satisfied with the naturally lit indoor space, fig (33).

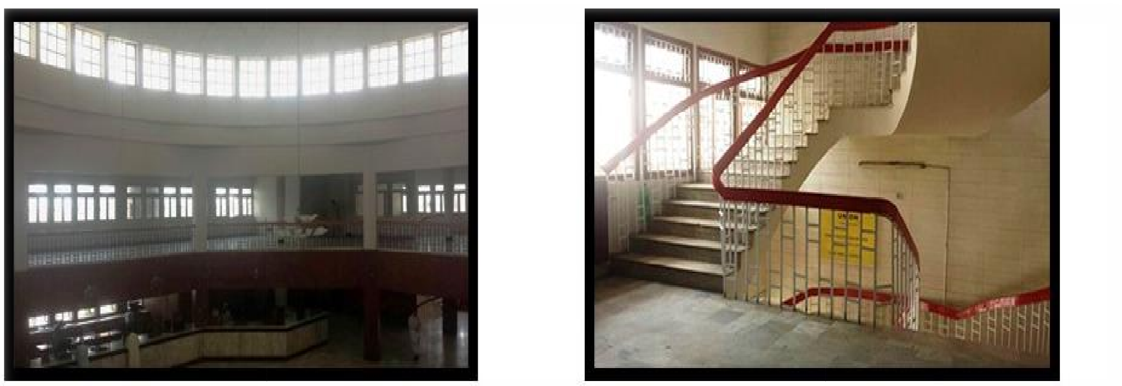


Fig (33) Natural Light inside the building

II. FAÇADE TREATMENT

In the GPO building, the walls on each façade have openings in the form of ribbon windows to acquire maximum air and natural light. In order to control large number of windows a unique design element of double façade is incorporated. The south and west façade are extremely important with reference to façade treatment. Here in GPO building the south facade is protected by another skin of wall. This wall consists of vertical louvers which help to reduce the effect of direct sunlight from southern side, fig (34). The wind coming from this side are also cooled down within the 3 feet cavity space (Fig35) between the two skins of facade.


Fig (34) Louvered façade

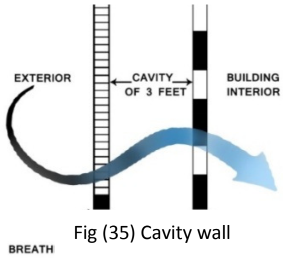


Fig (35) Cavity wall

West side of building is highly important in Karachi, with reference to wind direction, fig (36 & 36.1). Moreover, this side of building bears harsh evening sun rays. In GPO building an efficient cavity wall; interestingly articulated with repetitive ellipse and circle is working as protection barrier against direst sun rays.

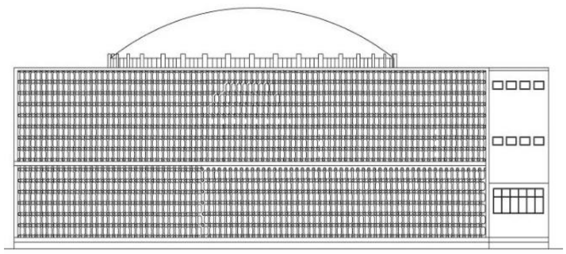


Fig (36) Façade treatment – East Elevation

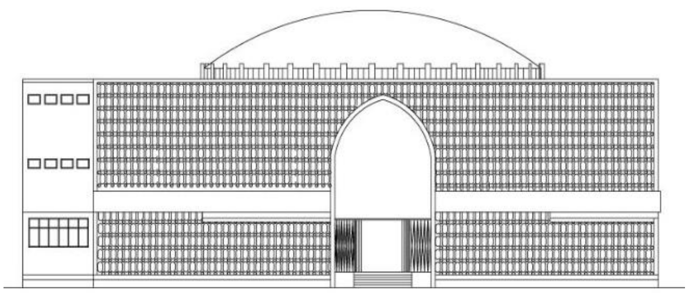
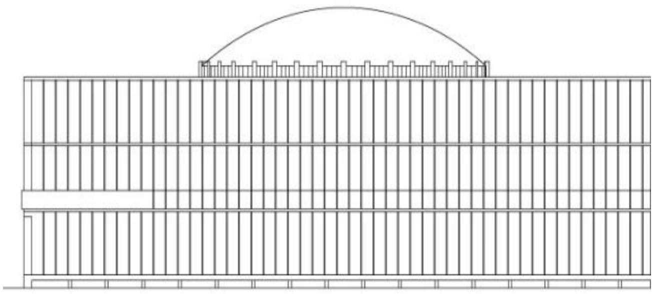
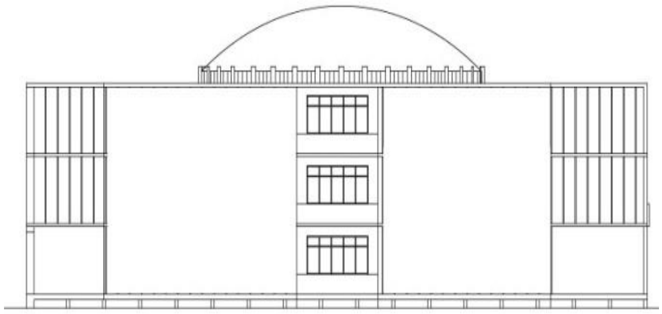

West Elevation


Fig (36.1) Façade treatment



South Elevation



North Elevation

The eastern side of the building is exposed to morning sun. A similar skin of cavity wall as west facade is attached to the east facade. The cavity between the two walls helps in cooling the wind and diffusing direct sun rays.

III. COOLING STRATEGIES

- **Ventilation:**

In GPO building, the overall profile of the building is square which is fenestrated with continuous ribbon windows that allows possible cross ventilation from windward to leeward side, fig (37).

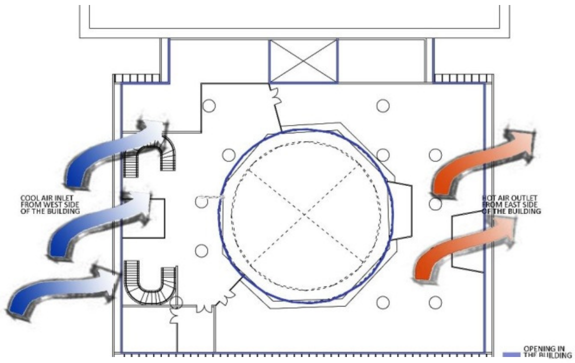


Fig (37) Cross ventilation

IV. VEGETATION

- **Trees on the Southern Façade:**

South and west façade of the building is screened with trees. West side is fenced with low heighted trees to allow more wind to enter in building, fig (38). Overall, this vegetation creates a thermal break from unnecessary solar radiations.

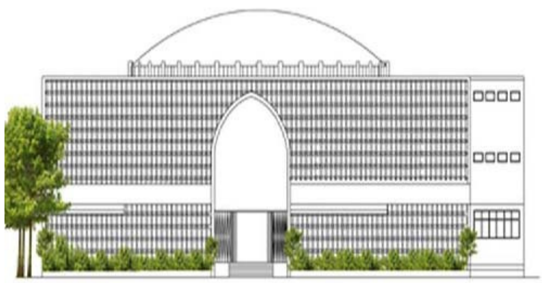


Fig (38) Vegetation

- **Courtyard:**

Courtyard is strategically located at the north side, which is attached with Postal Life Insurance building. This allows diffuse light and air in the relatively less fenestrated area, fig (39).

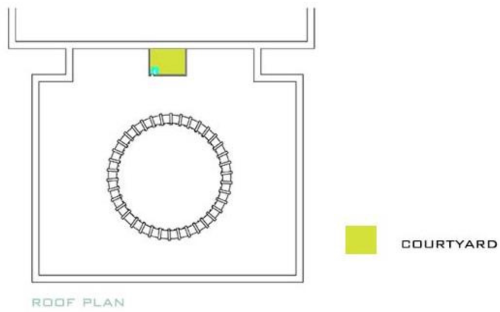


Fig (39) Courtyard

- **Open Plan:**

1. This building is designed on the principle of open planning. See Figure (40)
2. The main hall under the well-lit dome, houses the working spaces, which have low heighted glass and metallic perforated partition
3. walls, fig (42) to allow maximum flow of natural wind and light. See Fig (41)
4. The wide-open flexible plan promotes public interaction.

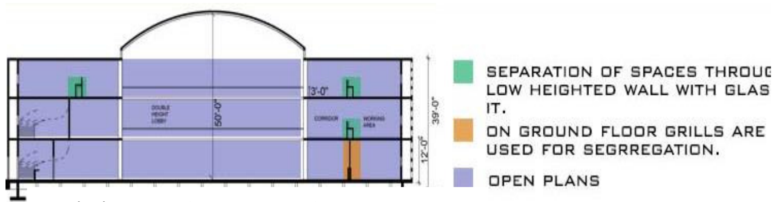
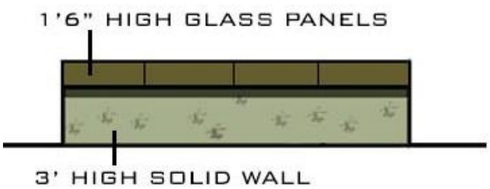


Fig (40) Section showing open planning

Fig (41) Building internal spaces segregated via low height partition wall to allow access to light & wind.



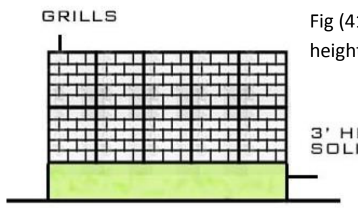


Fig (42) Low height partition walls

OPP RTI (ORANGI PILOT PROJECT, RESEARCH & TRAINING INSTITUTE)

BACKGROUND:

Orangi Pilot Project (OPP) is a NGO, which begin to work in Orangi town in 1980. It is situated at the periphery of Karachi. On the success of its five basic programs of low cost sanitation, housing, health, education and credit for micro enterprise, in 1988 OPP was upgraded into three autonomous institutions. OPP-RTI, OPP-OCT, OPP-KHASDA.

I. ORIENTATION:

The form of the building expands along both NORTH- SOUTH & EAST WEST direction fig (43). The building is oriented such that it allows maximum breeze to enter the building. Trees located on the south and west blocks the harsh sun rays to directly enter building.

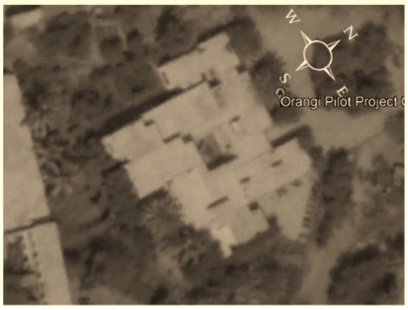


Fig (43) Orientation of the building

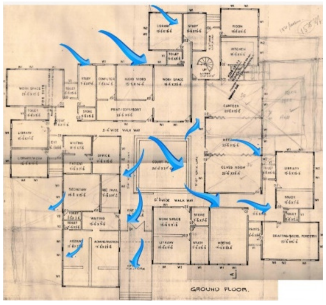


Fig (44) Wind pattern throughout the building

II. FORM

The cluster formation of this low rise building houses two courtyards. The larger courtyard of OPP RTI is centrally located, with an area of 576 sq. ft. The smaller courtyard, which acquires 144 Sq.ft. is placed on the northern side of building (See Fig 45). This organization of form around courtyard helps in creating conducive microclimate within the indoor spaces (See Fig 45).

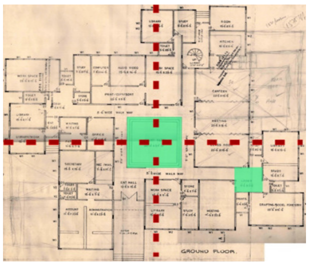


Fig (45) Placement of courtyards

Fig (46) courtyard

III. COOLING STRATEGIES

OPENINGS

Fenestration plays a significant role in lighting and ventilating any building. Here in OPP adjustable louvers are integrated in all opening to control daylight and wind(See Fig 47). These adjustable louvers allow or restrict direct sun rays and wind whenever needed.

Fig (47) Adjustable Louvers

COURTYARD

Courtyard helps to enter fresh air inside the building premises.

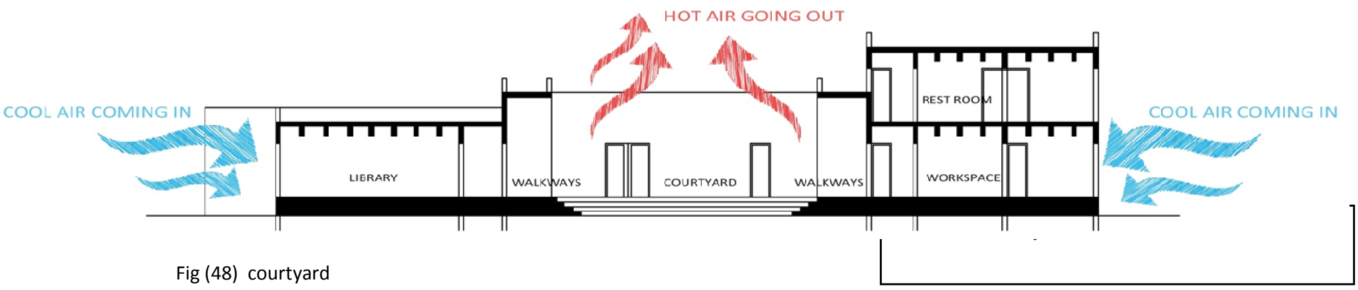


Fig (48) courtyard

WIND CATCHER

Wind-catcher is a traditional cooling duct, which catches prevailing wind and allows indirect sun light within the building. OPP houses four wind-catchers(See Fig 51). These wind-catchers also work as light wells because of its perforated envelope.

Fig (49) External View of Wind-catcher

Fig (50) Internal View of Wind-Catcher

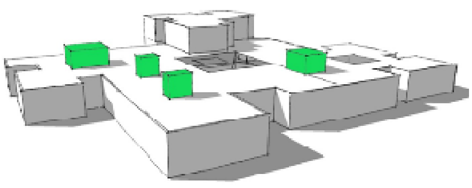


Fig (51) Placement of Wind-Catchers

VEGETATION

OPP is densely vegetated on its southern side with Neem, Palm, conocarpus trees.



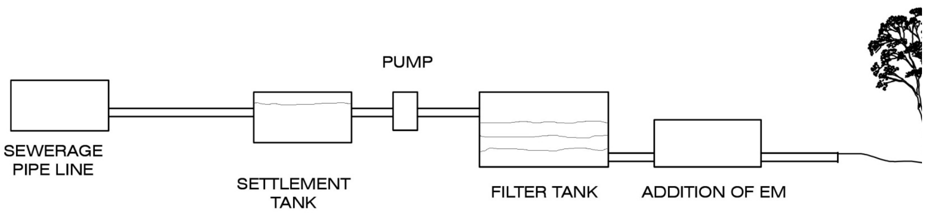
Fig (52) Vegetation

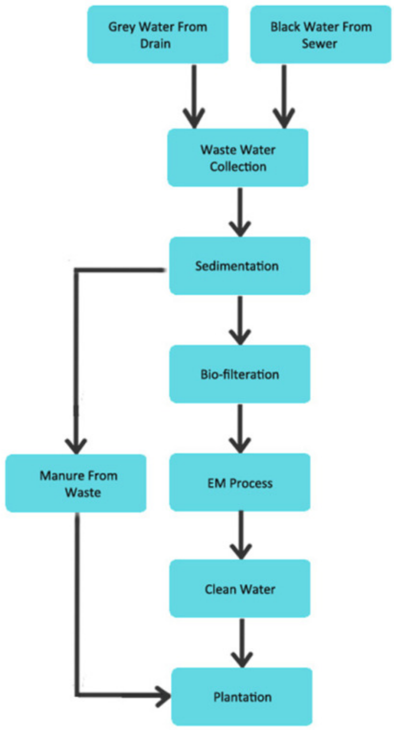
WASTE WATER RECYCLE:

The OPP-RTI recycles waste water generated by its users and general public sewers for urban farming. This recycling process is carried out using the following steps.

- Sedimentation
- Bio filtration
- Disinfection (Addition of effective micro-organisms)

PROCESS OF WASTE WATER MANAGEMENT AT OPP - RTI





STEP 1: SEDIMENTATION OF BLACK AND GREY WATER

In the OPP-RTI the black water from the general public sewers and building is collected in a huge tank, where it is subjected to the process of sedimentation. In the process of sedimentation black water is kept for 6-8 days. In this process all the undesirable suspended organic and inorganic material settles to the bottom of the tank due to gravity, which is further utilize as manure.

Fig (53) Sedimentation Tank

STEP 2: BIO-FILTRATION

After the sedimentation process the cleared water is transferred to another tank where it undergoes the process of bio filtration. In this unit it passes through various layers of bio filters that helps in removing contaminants and micro particles.

Fig (54) Bio- Filter Tank

STEP 3: DISINFECTION (EM PROCESS)

At the OPP_RTI the filtered water is collected in another tank, where EM (effective micro-organisms) are added in it. EM used in this process is composed of rotten fruit pulp, jaggery paste and water in the ratio of 1:3:10. 1cup of this mixture is enough for the disinfection of 1 barrel of water. EM's kill the harmful bacteria and reduces the foul smell from water and makes it fit for use in plantation.

STEP 4: CLEAN WATER USAGE IN PLANTATION

Once the dirty water has passed through the processes of sedimentation, filtration and disinfection it becomes fit for cultivation.

Fig (55) Urban Farming outputs

Key Features of OPP-RTI

The OPP-RTI is working for betterment of the underprivileged communities. key features of its architecture and community service are as follows:

- The building is made as a low-cost institution with the help of precast construction.
- The building finishing is carried out with fair face concrete which requires less maintenance.
- students at OPP-RTI are taught ways of making their living conditions better with reference to sustainability and environment
- Another worth noting initiative is usage of the recycled water in urban farming.
- Efficient consumption of vegetable/fruit peels and sludge as manure and fertilizers in the farms.

Overall OPP-RTI acts as a role model for sustainability in architecture through education and practice.

KMC MARKET

Introduction:

KMC market building is located in the heart of Soldier Bazar. Primarily, it is meat market with some basic plastic accessories, Vegetable and Fruit shops. It caters to large number of customers from Soldier bazar, Doli khata cantt and Garden area.

I. FORM

The form of the building is simple rectangle circumambulating around a huge court yard. See fig (56)

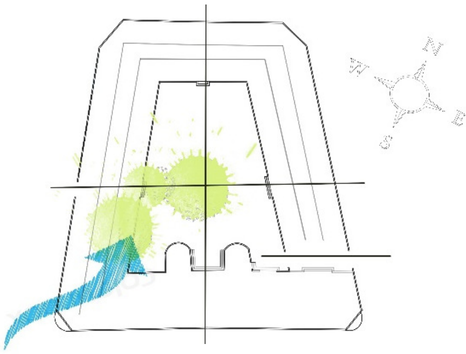


Fig (56) Rectangular Form

II. DAYLIGHTING

Fig (57) Day Lighting

The building is naturally lit all day long because of the large openings throughout the workstations, See fig (57). This day lighting facility helps workers to be more productive and helps in reducing electricity consumption.

III. COOLING STRATEGIES

Courtyard:

As mentioned above the form of KMC Market is courtyard type, the presence of courtyard improves the quality of air and helps in evacuating warm air. Moreover, presence of three huge trees inside the courtyard brings down the temperature and filters the air. It works as suction well to bring the cool air inside the building.

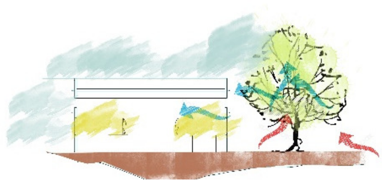


Fig (58) Court yard

Fenestration:

The KMC building has sizable number of openings, in the form of windows, doors, ventilators (Rohan dans) and screen (Mashrabiyas) which help in keeping the internal spaces well lit and cooler. See fig (60)

The high heighted circular Rohan dans are helping in creating stack effect thus maintaining thermal comfort of the users.

Mashrabiyas are sun screens with lattice work. It helps in allowing controlled sunlight and wind. This traditional screening system enhances the building façade and user comfort. See fig (61)

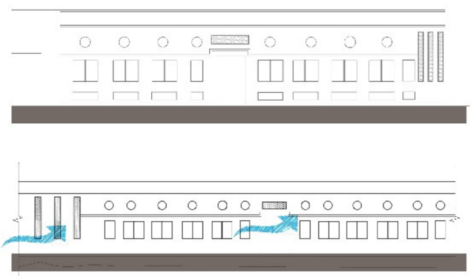


Fig (59) External Openings

Fig (60) Various Types of Opening

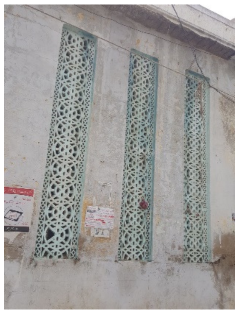


Fig (61) Mashrabiyas

MEGA TOWER G4:

Mega tower G4 is commissioned by Habib Bank Limited to serve as its head quarter. This high rise building is 27 stories above ground along with three stories basement floors. It is the first LEED (Leadership in Energy & Environmental Design) certified building in Pakistan.

Fig (62) Front View

I. FORM

The form of the Mega Tower building is compact with vertical linear growth. See fig (62)

II. COOLING STRATEGIES

Recessed Windows:

The building fenestration design is carried out with recessed windows. This window type is self-shading, which helps in preventing direct sun ray to enter the building. See fig (63)

Fig (63) Recessed Window

Raised Floor:

In the Mega tower, the air conditioning load has been reduced with help of raised floor at about one feet height. Basically, this system helps in curtailing excessive room area to cool. It focuses on the habitable area for building users. This building is also equipped with an under-floor air distribution (UFAD), which push the warmer air upwards and quickly provides thermal comfort.

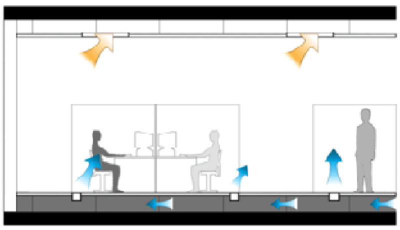


Fig (64) Raised Floor and UFAD

Insulated Building Envelope:

An efficient building envelope can help in controlling heat transfer through conduction, radiation and convection. Here in Mega tower the designers opt for minimum fenestration on the southern side. This building utilizes 24mm thick insulated glass unit, which is composed of :

- Outside 6mm thick Crystal Grey and Euro Grey fully tempered glass.
- Inside 12mm Airspace and 6mm thick fully tempered clear glass.

Furthermore this building utilizes low U-value and low voc (voltaic organic compounds) materials cladding material. Matrix (1)

ENVELOPE COMPONENT		
ENVELOPE COMPONENT	U – VALUE(BTU/FT^2/HR °F)	SHADING COEFFICIENT
WALLS	0.448	
ROOF	0.0915	
FLOOR	0.298	
WALL PARTITION	0.362	
WINDOWS/GLAZING 1	0.297	0.301
WINDOWS/ GLAZING 2	1.022	0.706
WINDOWS/ GLAZING 2	1.022	0.706

Matrix 1: Envelope component of Mega Tower Source: Engr. Farhan Adil Mehboob

Co_2 Sensors:

Mega tower is equipped with CO_2 sensors to provide fresh air, when CO_2 level rises due to presence of users the system start to work and pumps fresh air. . It is also known as occupancy sensor. When the people leave, the CO_2 level drops then fresh air dampers once again get close.

On the contrary, the conventional system air conditioning gulps large amount of energy due to excessive provision of conditioned air while space is un-occupied.

HVAC Load of the Building

The cooling load of the building is 3900 tons, which is being fulfilled by 3 chillers. Usually for one ton, it takes 1.6Kilo Watts but the Mega tower utilizes 0.6 KW/Ton, because of its energy efficient design in terms of mechanical and architectural reforms. Moreover, it utilizes 18 less energy as compare to conventional high rise building.

III. WATER EFFICIENCY:

The building has an water efficient plumbing system, which utilizes all chillers distilled water for washing purpose.

SECTION 3

USER FEEDBACK ANALYSIS

As this research is based on case study approach, 20 users from each building between the age group of 20-50 have been randomnly selected for the questionaire survey in order to analyze their personal experience of comfort (thermal, visual, air quality and acoustics in respective case studies.

OCCUPANT COMFORT

Spaces and buildings are designed for people who are designated to fulfill some task, whether it's manufacturing a product, managing an office or raising a family. The building should be comfortable, healthy and sustainable when one set for a task. (Ashrae, 2016)

The sustainable design approach helps to achieve a solution with minimum negative environmental impacts. Apart from thermal comfort there are parameters like visual, air and acoustic comfort which are discussed below:

a. Thermal Comfort

Thermal comfort refers to the temperature that is neither too warm nor too cool. This has to be in human comfort zone. Thermal comfort is important for health as well as productivity. Lack of thermal comfort causes stress among the users of the building therefore a comfortable environment which is thermally balanced should be provided and designed. Thermal comfort depends upon air temperature, humidity and the movement of the air.

b. **Visual Comfort**

Maintaining visual comfort means ensuring that people have enough light for their activities, the light has the right quality and balance, and people have good views. *Good light promotes a healthy and productive environment. A proper sight-lines and good views gives user a control on its environment and task and natural light do this in much better way than and electric resource*. (McGraw-Hill, 2012)

c. **Air Comfort**

In addition to air that's the right temperature and humidity for thermal comfort, it's important that air is clean, fresh, and circulated effectively in the space. If the air quality is too polluted and stale then people would be unhealthy, unproductive, unsafe and sick.

Air quality is kept fresh by proper ventilation, either using natural ventilation such as windows and skylights or active systems like HVAC and ducts. Clean air can be achiev d within building premises by filtrating air, pushing fresh air from outside within building spaces and not contaminating air with impurities produce by buildings paint and material such as volatile organic compounds, lead and CO emission.

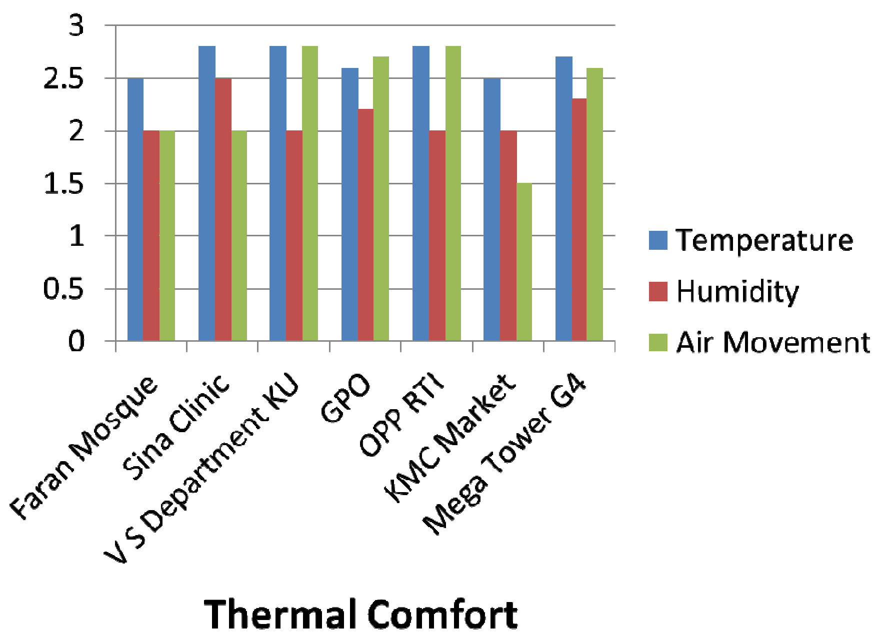
d. **Acoustic Comfort**

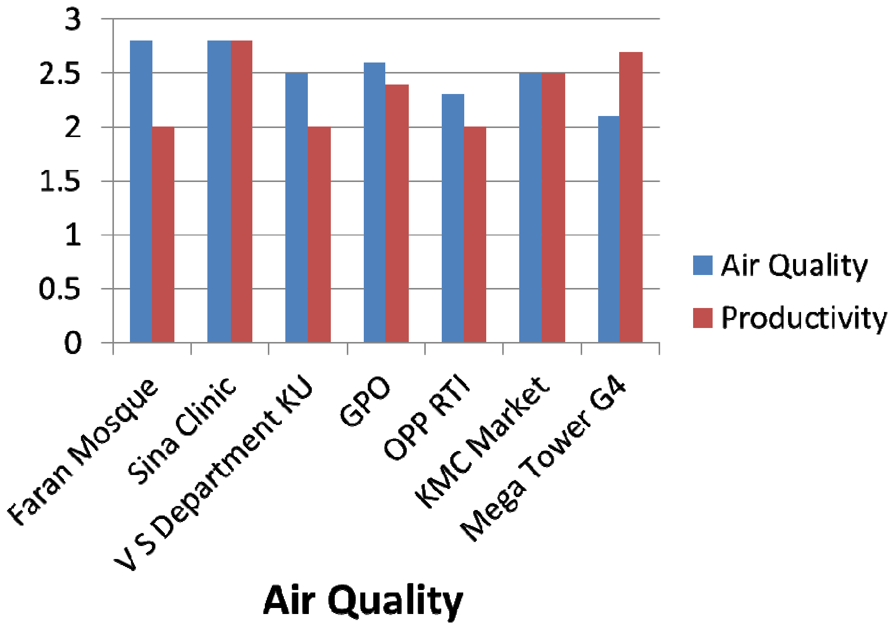
Acoustic comfort means having the right level and quality of noise to use the space as intended. *People are more productive and comfortable when they are not disturbed or distracted from noises outside and noises within the parameters of a building, this comfort is really important in school; and office buildings*. (McGraw-Hill, 2012).

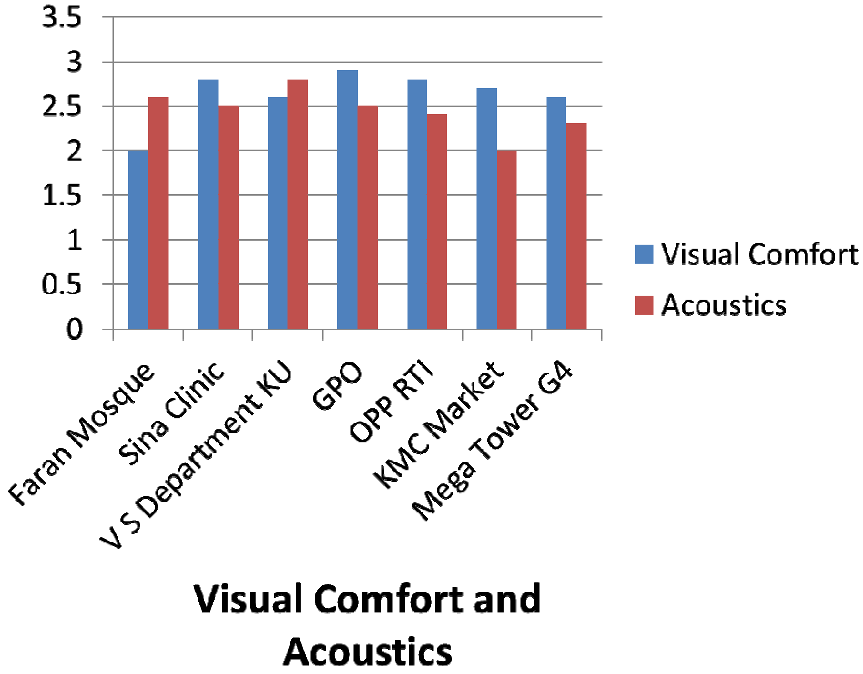
SURVEY FINDINGS

Through survey it is found that all the selected buildings come under comfortable zone. They are thermally comfortable because of efficient use of materials and ventilation. The selected case studies are well lit with controlled diffused light during day time with the use of appropriate shading devices thus visually comfortable, more productive and energy efficient. The air quality of majority of selected buildings are well managed through passive means i-e having proper inlet and outlet of fresh air which leads to more healthy and productive indoor environment. Most of the selected buildings are sound acoustically in terms of creating buffer spaces in between exterior and interior. These buffer spaces serve dual purpose i-e act as sun barrier as well as noise barrier.

GRAPHICAL ANALYSIS OF USER FEEDBACK




3
2.5
2
1.5
1
0.5
0
Air Quality
Productivity
Faran Mosque
Sina Clinic
V S Department KU
GPO
OPP RTI
KMC Market
Mega Tower G4
Air Quality


3.5
3
2.5
2
1.5
1
0.5
0
Visual Comfort
Acoustics
Faran Mosque
Sina Clinic
V S Department KU
GPO
OPP RTI
KMC Market
Mega Tower G4
Visual Comfort and Acoustics

SECTION 4

EXPERT OPINION

An interview with Architect and Planner Arif Hassan

According to Arif Hassan, Karachi has witnessed 47 degree Centigrade in 1939 and 46 degree Centigrade in 1981 but no causality was recorded at that time. But, in May 2011, 46 degree Centigrade temperature has caused death and heat wave related illnesses in Karachi. Moreover, the case of 2015 heat wave is an open herald for everybody that temperature doesn't kill people; it is the building design, road construction and greenhouse gas emissions, which kill people.

He suggested to extract, best out of climatic conditions like orientation of buildings along with proper fenestration and insulation. According to Arif Hassan, Karachi's climate require smaller wind inlets and large outlets to acquire fresh air and evacuate hot internal air during summer season. Furthermore, this fenestration design can work more efficiently, if inlet windows face vegetation. He recommended local tropical plant species to avoid excessive water consumption. He shared case example of his project, SRSO building located in Sukkur. In which he incorporated locally available construction materials with the idea of cavity walls and courtyard with native plants.

He fostered importance of locally available materials with engineering innovation on the principle of miniaturising the technology and passing it on decentralization approach to the grass root level. This can be carried out by building a liaison between the local manufacturers (Thallay Wallas) and professional i.e. architects and engineers. He identified the potential of research on light weight aggregate and low cost insulating materials including paints. He pinpointed role of electrical engineer in minimizing electricity consumption with the help of energy efficient tools and gadgets like LED Lights, inverters, air conditioner out door unit insulating covers.

Arif Hassan suggested efficient use of grey water especially for vegetation. He emphasized on installation of individual house meter or at least bulk metering and solar powered underground water pumping.

According to Arif Hassan, climate responsive architecture is the fundamental tool to carve the real style of Pakistani architecture. Which is unfortunately, fogged behind the blind following of international architectural styles.

An interview with Architect Afzal Ebrahim, Green and Sustainable Buildings Expert

According to Architect Afzal Ebrahim, the sustainability and climate responsiveness was an integral part of Pakistani Architecture, especially in pre-partition phase and then early phase of post partition. He acknowledges the old architecture of Hyderabad, Sindh, where the city skyline geometry was defined by the passive cooling wind catchers (*Mangh*), to provide cool air in the buildings during summers. It is also evident in Karachi that building design during that time, took the cue from prevailing wind and high ceiling with vent to maximize on natural ventilation to cool the building occupants.

Likewise, thick mud walls in rural architecture were adequate to prevent cold and hot outside conditions to enter the buildings due to its thermal lag properties. He also spread light on the dramatic change in human thermal comfort level, which is tilting the pivot towards energy intensive air conditioning.

In this domain he suggested to devise architectural design in 3-tier method: The first tier is the passive methods to prevent heat entering a building in a warm/hot climate or to promote heat entering the building in a cold climate. The second in the tier is to use passive methods, such as ventilation cooling in summers and solar heating in winters, to provide human thermal comfort in buildings. If the two preceding tiers do not provide human thermal comfort in buildings to a certain required minimum, then active cooling such as using evaporative cooling or air conditioners could be used in summers and natural gas or electric heating could be used in winters. This three tier strategy can be help in reducing electricity consumption, hence curtails the environmental degradation.

According to Ar. Afzal Ibrahim, energy-efficient architecture directly relates to building orientation, building surface area to volume ratio, insulated envelope, natural lighting, responses to the natural weather elements, geo-exchange, use of solar energy for heating, natural ventilation, terra-tecture, radiative and evaporative cooling, roof ponds and green roofs. He finds huge potential in retrofitting of building in order to reduce energy crises in Pakistan. For retro fitting, he suggested insulation as the first and foremost important element. This element is not only highly successful in passive energy efficient building but also helps in controlling temperature variations in active energy dependent buildings. He further suggested to improve ventilation cooling, solar energy based heating, photovoltaic cells on rooftops for power generation, switching to energy efficient appliances and air-conditioning units.

Lastly, He spread some light on the role of government in promoting energy efficient material and gadget via patronage and subsidy on it.

SECTION 5

RECOMMENDATION

5.1. Design Recommendations

Overall, the current situation demands a close connectivity of built environment with climate so that buildings do not serve as an individual unit.

One of the famous design principles associated with 20th century is *form follows function*, which prescribes the form of building according to its proposed purpose or function. The current situation of environmental degradation due to increasing energy demand to maintain comfort level in build structures is paving a path towards a new strategy, *form follows climate and energy*. So that construction industry can minimize its carbon footprint via less consumption of energy and resources. This can also help in minimizing the adverse effects on social, ecological and economic balances.

Following is a checklist of efficient climate responsive design elements, workable in the context of Karachi city.

CLIMATE RESPONSIVE DESIGN ELEMENTS	FARAN MOSQUE	SINA CARE CLINIC	VISUAL STUDIES DEPT. KU	GPO BUILDING	OPP RTI	KMC MARKET	MEGA TOWER G4
Energy efficient envelope	✓	✓	✓	✓	✓	✓	✓
Courtyard	✓	✓	✓	✓	✓	✓	
Windcatchers	✓				✓		
Overhangs		✓	✓	✓	✓	✓	✓
Verandah		✓			✓		

Ceiling height	✓	✓	✓	✓		✓	✓
Insulation	✓	✓	✓	✓			✓
Sun breaker		✓	✓	✓	✓		
Skylight	✓		✓				
Waterbody			✓				
Louvers			✓		✓		
Vegetation	✓	✓	✓	✓	✓	✓	
Insulation via wall thickness	✓		✓			✓	
Water efficiency	✓				✓		✓
Material efficiency	✓	✓	✓	✓	✓	✓	✓

The aforementioned climate responsive design elements along with proper sized energy efficient equipment for heating and cooling can bring a positive change in user comfort and energy consumption. This can be further improved with the help of maximum use of renewable energy resources as a building component.

5.2. Policy Recommendation

- ✓ Phase wise improvement plan

The urban sprawl of Karachi demands extensive mitigation and future strategies to encounter issues related with build environment. One of the primary tools to mitigate this issue is retrofitting. It can be undertaken in both active and passive energy efficiency features. For examples, alteration in fenestration design according to wind direction or installation of a more efficient HVAC system, or investment in building automation system can bring about huge differences in particular domains.

- ✓ Integrating environmental considerations in building byelaws

A complete set of building byelaws based on energy efficiency, water efficiency and environment regenerating measures should be integral part of building design byelaws.

- ✓ Strengthening capacity

It can be achieved with help of phase wise demonstration and outreach plan to advocate the importance of climate responsive aptitude and attitude in larger masses. This can be a thematic campaign on print and electronic media. On the later phase, outreach can expand to training and awareness campaign in various strata of society.

- ✓ Regular review by competent authority

A strict system of compliance must be formulated in order to keep a check on the quality of build environment. An encouraging system of appreciation and awards to high achievers can be good yard stick to analysis the overall improvement.

SECTION 6:

CONCLUSION AND FUTURE DIRECTIONS

The in-built ecosystem of planet earth must go hand in hand with the build environment to avoid radical and irreversible changes in environment. Climate responsive architecture is the key to achieve sustainability and environmental protection. Climate friendly buildings are not just helping in derailing adverse environmental degradation, but they are equally beneficial to the people residing in terms of comfort and reduced overhead cost.

In a nutshell, proper land use planning, efficient design interventions along with appropriate material selection and use of renewable energy resources can bring exponential positive change in built environment.

Further extension of this study along with action programme can be devised to cater following domains:

- ✓ To serve low income settlements
- ✓ Expanding scope of study to other climatic zones in Pakistan

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APPENDIX

SURVEY FORM:

<u>User Comfort and Energy Efficiency in Public Buildings of Karachi</u>

Building Name ____

Building Type____

Gender_________________________________ Age ______________________________

<u>Location Within Building</u>

<u>Q.1.</u> On which floor is your workspace located?

First Floor

Second Floor

Third Floor

<u>Q.2.</u> In which area of the building is your workspace located?

North

East

South

West

<u>Q.3.</u> Are you within 15 feet of an exterior wall?

Yes

No

Q.4. Are you within 15 feet of a window?

Yes

No

(Thermal Comfort)

Q.5. Temperature (High, Low)

-3	-2	-1	0	1	2	3

Very Dissatisfied Very Satisfied

Q.6. Relative Humidity (Humid, Dry)

-3	-2	-1	0	1	2	3

Too Cold Comfortable Too Hot

Q.7. Air Movement (High, Low)

-3	-2	-1	0	1	2	3

Too Cold Comfortable Too Hot

Q.8. If you experience thermal discomfort (temperature and humidity), which of the following best describes it?

Too much/ too little air movement

Incoming sunlight heats up space

Heat from office equipment

Drafty windows

Vented air is too hot

Vented air is too cold

My workspace is hotter than other areas

My workspace is colder than other areas

Hot floors and walls

Cold floors and walls

Thermostat is inaccessible/ controlled by others

Other (Please explain below)

Q.9. Please describe any other issues related to your thermal comfort in your workspace:

____
____
____
____

Air Quality

Q.10. How satisfied are you with the air quality in the building?

-3	-2	-1	0	1	2	3

Very Dissatisfied Very Satisfied

Q.11. Overall, does the air quality enhance or interfere with your productivity?

-3	-2	-1	0	1	2	3

Interferes Enhances

Q.12. If you are dissatisfied with the air quality in the building, is it:

Stuffy/Stale

Odorous

Q.13. If the air is odorous, is it due to:

Tobacco Smoke

Photocopiers/Printers

Food

Carpet/Furniture Systems

Other (Please explain below)

____-
____

Acoustic Level

Q.14. How satisfied are you with the acoustic level in the building?

-3	-2	-1	0	1	2	3

Very Dissatisfied Very Satisfied

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