279 Adaptive urban form design on a climate change basis A case study in Nubia, Egypt

Mohammad Fahmy[1]*, Hany Mokhtar[2] and Amr Gira[3]

Military Technical College, Cairo, Egypt [1]*
md.fahmy@live.com
Military Technical College, Cairo, Egypt [2,3]

Abstract

Achieving pedestrian thermal comfort in hot arid zones can be considered a parameterization method to adjust urban physical form as well as to close to indoor comfort. Pedestrian thermal comfort is a cumulative parameter strangely related to the urban patterns and housing typologies generated from a specific urban planning methodology. Radical practiced urban planning in Egypt does not consider passive urban design strategies to help reducing heat stresses. Therefore, this study investigates the microclimatic thermal behaviour of an urban village (New Karkar village) in Upper Egypt at which maximal climate conditions can be recorded in Egypt. Two model cases were examined for the same site through studying its existing and passively suggested pattern in order to establish implications for urban form design on an impact assessment basis as if those strategies were considered. Numerical simulations were performed using ENVI-met software for a hot summer day in each case in present and future. Outputs of Tmrt, radiant temperature standing for the radiation environment of the village form design were averaged using a simple visual basic tool to generate a representative comfort indicator as Tmrt summarizes all net wave radiation incident on a pedestrian at different times as a sustainability indicator for the whole village conditions. Climate change scenarios of the year 2050 and 2080 have been morphed and used in simulations to compare thermal performance against present day radiant temperature records. Results proof that achieving acceptable comfort levels and cooling potential in the future necessitates the application of more intensive urban passive design tools compared with present day.

Keywords: passive design, climate change, air temperature

1. Introduction:

1.1 Climate based urban planning

Urban developments have short run cost, and long run cost as well. From a thermal performance point of view it considers human thermal comfort, energy consumption and climate change [1-3]. Climate based urban planning is a multidisciplinary interacted group of fields such as Meteorology, human biometeorology, architecture, urban planning, urban design, landscape and landscape architecture, physics, human physiology, remote sensing, urban management….etc [4, 5]. To start work in an urban planning and development case considering climate change, urban planner and designer should define its corresponding climate scale, have a basic knowledge of urban thermal interactions and urban passive strategies and have to know what urban passive system is [6]. Up to about 1km2 is corresponding to local climate scale which in turn is corresponding to a neighbourhood/village site area [7]. The bigger the scale of urban site and in turn its climate scale, the more complexity of designing urban form is [8, 9]. An urban passive system is then an adjustment for the built environment three physical elements affecting its thermal performance and in turn all related sustainability issues, these are fabric, network and vegetation [7, 10-13]. Using present day climate conditions reveal an assessment for the built environment morphology, therefore, predicting future conditions under climate change scenarios, [14] reveal the capability to asses physical design of built environment in the future [5]. Urban street canyon thermal studies have been presented by many researches [15-18], for only single cross section which doesn't represent a whole neighbourhood/village thermal performance when assessing different alternatives. As cities are considered agents for regional/global climate [19], neighbourhoods/village are considered the agents for cities climate [6] as they are the urban planning units for them [20]. For that purpose, Fahmy [21] presented an averaging methodology for meteorological parameters of all local scale urban spaces to represent whole neighbourhood/village. Consequently, urban form alternatives can be objectively assessed in present and future on a climate basis as well as on other urban design appraisal methods [22-24] to support decision making. Future conditions refers to climate change scenarios reported by the Intergovernmental Panel for Climate Change [25], which are generated for the years 2020, 2050 and 2080 either by morphing or stochastic methods [26, 27]. It is argued that major climate change effects in Egypt will be air temperature increase as well as a recess in the Nile delta due sea level rise of about 20-60cm which means temperature increase, thermal sensation and comfort levels. Therefore, urban developments should account not only for present day conditions, but also for future ones.

1.2 Urban development in Aswan

Upper Egypt urban development major projects started about 20 years ago by coupling the east river Nile cities with new parts at the river west bank. One governorate of this Egyptian region, Aswan, (N 23° 58'- E 32° 46'), has an international reputation for its cultural heritage and the open historical built environment showing the monumental development that ancient Egypt had. For this reason and to protect such treasures along with the hidden ones under Nubia old villages' houses, a massive urban development project has been launched for southern part of Aswan, the Nubia, and had the fund and political support. Nubia is the region starts around Lake Nasser and continues into the lands of Sudan, its people has their deep history in contact with ancient Egypt, and their villages can be distinguished through the works of the late famous Architect Hassan Fathy [28]. As part of NUBIA urban development project, relocating some old villages has been decided to consider them antiquities protectorates due to the many discoveries found under houses. NUBIA had the opportunity of designing a community of eight urban villages to the west of Aswan International Airport of about 10km. Such conditions guided the vernacular Nubia urban villages towards compact forms with narrow streets, mud walls and thermal masses along with light colors and courtyard housing. The average population density of Nubia villages is 28 p/feddan [29].

1.3 Case study

The site is located in Karkar Nubian area about 10km to the west from Aswan International Airport, fig.1. With area of about 494 feddans (feddan is about 4200m2), and divided into eight villages planned to accommodate about 10000 people of about 1200 for each village, urban planning was radically guided from the government after geotechnical, social and economical studies but with minor consideration for climate.

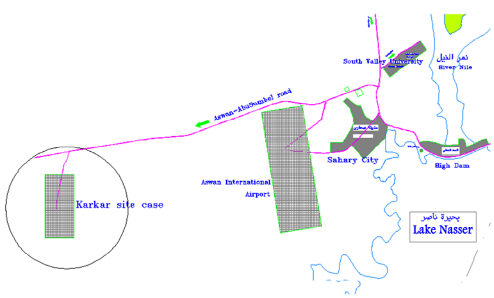


Figure (1): Nubia region map indicating Karkar site in relation to Aswan city of which the High Dam lays at the centre.

This appeared in the concrete skeleton construction of the service buildings and absence of passive design techniques, fig.2, regardless the vernacular form of fabric.

Based on 30 years of WMO Station no. 624140, the region is classified as Subtropical hot desert characterized with harsh conditions of unbearably hot dry periods in summer, but passive cooling is possible [30, 31]. With less than 20% of relative humidity and 8770 Wh/m² of daily global radiation, its extreme hot week period lays between Jun 29th: Jul 5th, maximum air temperature of 47.5°C, whereas the typical week period between Jun 8th: Jun 14th, average air temperature of 34.1°C. The extreme summer hot day is the 1st of July, fig. 3, as analyzed by ECOTECT2010 [32].

Figure (2/a, b): Design sets illustrations for; 1 to the left and 2 is right.

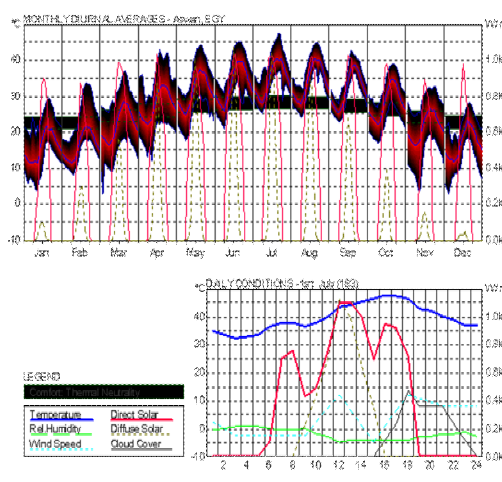


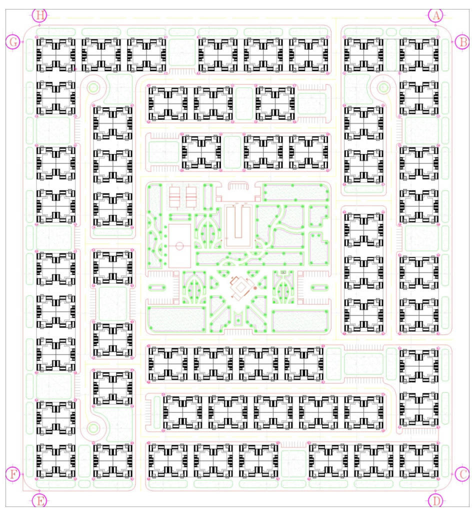
Figure (3): Meteorological measurements at WMO weather station no. 624140 of Aswan corresponding to the extreme hot summer day analyzed by ECOTECT2010.

Table 1 shows urban planning statistics for the already approved proposal for one of the villages in comparison with newly suggested proposals as if passive strategies were considered.

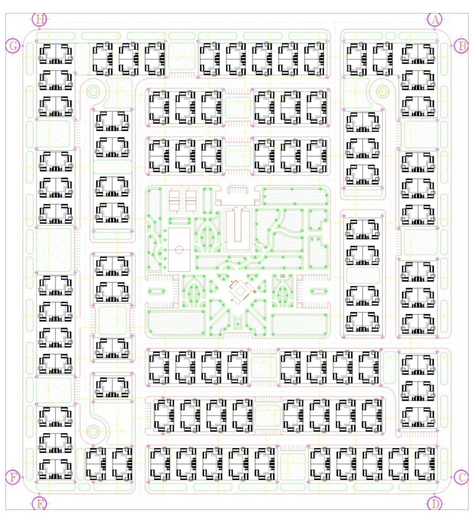
Table (1): Housing design and land use statistics

	of design alternative	total area	Green coverage	urban construction	No.of families	Total population	Population /feddans
1	Base Case		18.5 %	17.4 %	224	1120	28.8
2	proposal 1	38.92	18.0 %	14.8 %	180	900	23.1
3	proposal 2		18.0 %	14.8 %	360	1800	46.2

The main difference in the urban form of the first alternative is the fabric orientation in addition to separating the four housing units from being clustered around single courtyard. second alternative applies more dense housing using two floors instead of one and less court exposed area which means more compactness degree and hence an expected better thermal performance [6], fig. 4, Show the urban design for the base case and the proposal, Fig. Show5 indicates a 3D visualization for the two alternatives.



(4/a)



(4/b)

Figure (4/a, b): Show the urban design for the base case and the proposal

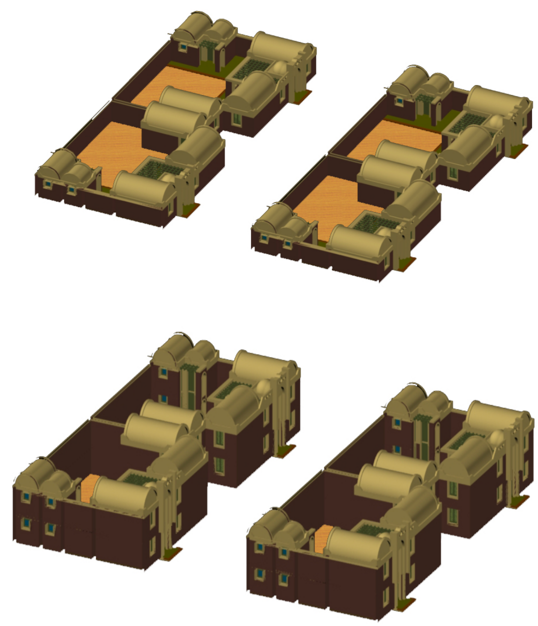


Figure (5/a, b): 3D visualization for the two alternatives.

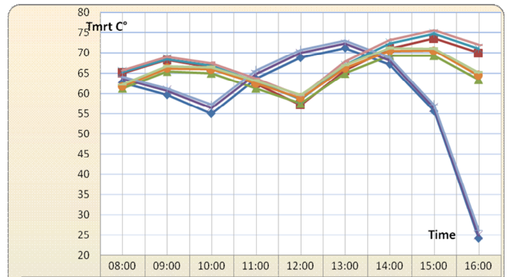
2. Methodology

In order to support the design decision by giving an advantage for one of the proposals, an assessment for the whole urban form design outdoor and indoor thermal performance took place as both of them are important for accreditation of one of them than another. The conductive heat relation between outdoor and indoor climate conditions consequates particular indoor thermal comfort levels which in turn defines other sustainability measures such as energy demand and carbon emissions. Simulation was the preferred method due to the large area of the case study as well as the non-representation for the whole site if measurements took place at selected points. Most of thermal performance simulations tools use files of the open horizon meteorological data measured at a distance from urban, therefore, an outdoor conditions' parameter had to be investigated as well as its corresponding indoors to refer to specific urban form details rather than the open horizon. From these standing points, mean radiant temperature averaged at 1.2m above ground level for 10h to represent outdoor environment thermal performance through the numerical simulation model ENVI-met BETA5 on the 1st of July as an extreme summer hot day in Aswan. ENVI-met is a CFD microclimatic model which is capable of simulating the built environment surface-air-plant thermal interactions based on the fluid dynamics and heat transfer fundamentals, solar movement and vegetation databases and it proofed reliable usage in the scope of environmental impact assessment [33]. The later study concluded that a complete vision about urban development thermal performance should couple both outdoor and indoor investigations as urban spaces affect the indoor comfort and energy consumption. Moreover, climate change weather scenarios were generated using CCWorldWeatherGen [34] that applies the morphing methodology [26] to predict mean radiant temperature for base case and the modified proposals at the year 2050 and 2080. CCWorldWeatherGen uses present day weather data file compiled in an Energy Plus file with ETMY format [30] to generate new file for the targeted years; 2050 and 2080. This means that each proposal had 3 outdoor assessments for present day and future at 2050 and 2080, and hence the total simulations are 9 each of them took about 5 days to simulate 9h of the selected day. To ease writing the names of proposals, base case will be named BC, the 1st proposal will be P1 and the 2nd proposal is P2. For present day simulations abbreviation is PD and for climate change scenario at 2050 simulation called CC2050 and for climate change scenario at 2080 simulation called CC2080. So the 2nd proposal in 2050 can be named as P2CC2050.

3. Results and analysis

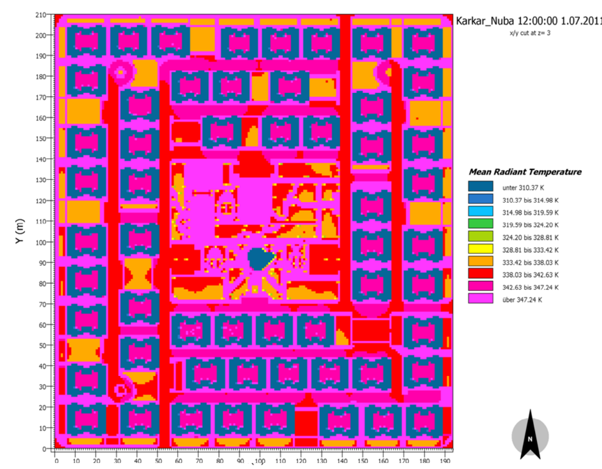
The trend of Radiant Temperature curves for the base case master plans at present day and future simulations are the same, also the curves for the two proposals at present day and in future but with small difference according to climate change, increasing at noon and start to decrease by evening. The extreme radiant temperature degree for the Base case was 71.1C° at 13:00pm since the Proposal1 was 65.6 C° and Proposal2 was 64.9C°. At 8:00 am the radiant temperature for the base case was 62.7C° where the proposal1 was 65.0C° and proposal2 was 61.3C°, but at 4:00 pm the radiant temperature for the base case was 24.1C° where the proposal1 was 69.9C° and proposal2 was 63.4C°.

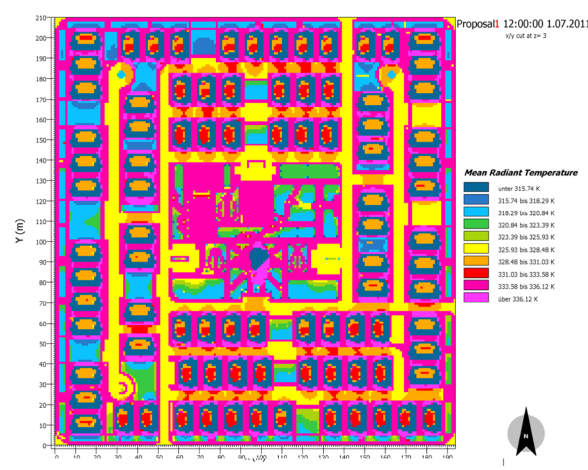
It is then clear that proposal1 and proposal2 achieved more thermal comfort at peak time from 11:00 am till 2:00 pm than the base case. Since the fabric building materials are the same, it can be argued that the more open sky view factor (SVF) of P1PD contributed to more gain of direct solar radiation. SVF of BCPD was 0.86 whereas for P1PD was 0.87 in turn the shaded area of BCPD was more than P1PD. Consequently, there are two options to achieve more shaded area and less SVF. Either to increase vegetation compared with BCPD or to increase the building-street aspect ratio H/W to generate more shade.



	08:00	09:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00
Bc PD	62.7	59.6	55	63.6	68.8	71.1	67.1	55.6	24.1
P1 PD	65	68.2	66.4	62.4	57.1	65.6	71	73.5	69.9
P2 PD	61.3	65.4	65	61.3	57.5	64.9	69.3	69.3	63.4
BcCC2050	63.6	60.7	56.4	64.8	69.9	72.2	68.1	56.4	24.8
P1CC2050	65.3	68.4	66.8	62.9	58.5	66.9	72.3	74.7	71
P2CC2050	61.8	66.1	65.9	62.5	58.8	66.2	70.4	70.5	64.4
BcCC2080	64.1	61.3	57.2	65.6	70.6	72.9	68.8	57.1	26.1
P1CC2080	65.7	68.9	67.4	63.6	59.4	67.8	73.1	75.5	71.9
P2CC2080	62.2	66.6	66.4	63.1	59.6	66.9	71.1	71	65.1

Figure (6): Radiant temperature curves for the base case and the two proposals at present day, 2050 and 2080.





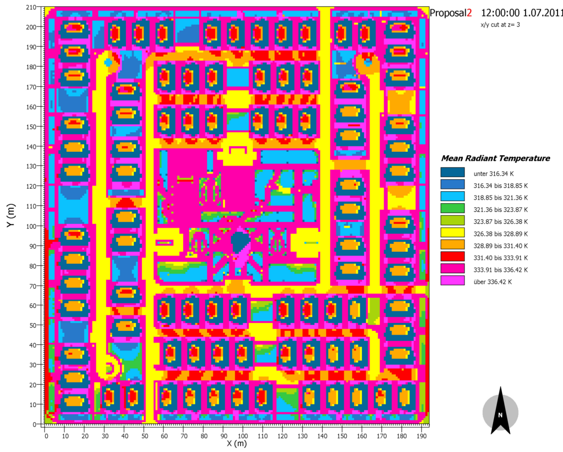


Figure (7): Tmrt mapping for BCPD, P1PD, P2PD respectively, at 12.00 LST.

4. Conclusions:

This paper discussed the microclimatic effects of an urban village form in Karkar, Nubia. The already existing form hasn't considered passive design strategies; therefore, this work suggests another two urban forms as if passive strategies have been considered. The two proposals were designed on the same land use without changing fabric morphology or housing typology. So, the only way to increase urban compactness of the village was to increase the heights to conclude more shading. By increasing the compactness using more floors, both proposed urban village forms showed more comfortable outdoor spaces at peak time. Despite this happened, the base case showed more comfortable urban spaces before and after peak time (11:00 – 14:00LST). It can be argued that introducing passive strategies in the late design stages as presented in the work didn't affect whole the day time comfort.

From this standing point, such approaches of passively designed physical form weather urban or not, should be embedded in the design process to show more control on the built environment climate by controlling the land use and the fabric morphology themselves.

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