Natural ventilation and building low energy cooling as new culture for city planning design

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ABSTRACT

Innovative development strategies for a “Mediterranean urban planning project” for the city of Umbertide-Umbria, organized in a new ecological, bioclimatic and energy sensitive residential/mixed-use, car free district of 1.500 inhabitants, focused on an appropriate natural ventilation system. The work involved participating with the local community on the design brief and urban comfort master-planning concept. Extensive climatic analysis and computer modelling has been carried out to test the design concepts.

1. INTRODUCTION

Today the progressive “changing of climate” force us to redefine concepts and principles of sustainable and bioclimatic design. During the recent years, the concept of bioclimatic house has evolved to what can now be considered a “sustainable housing”. Currently sustainable housing appears to place emphasis on “energy” as the main environmental impact that should be reduced. This definition can be found from the aims of the International Energy Agency IEA/SHC programme Task 28 on “Solar Sustainable Housing”. Until now, such housing in a advanced north European theoretical and applied research, achieved this performance, primarily by reducing heat losses through compact building form, thick insulation and ventilated heat recovery. The number of such buildings is growing, within a market penetration with the production of very well insulated house and increasing energy gains that can be achieved by passive solar design, active system for hot water and space heating; PV electric supply systems (IEA,2004)

If all that can be appropriate for Northern climate, for any other context of Southern temperate and warm climates, a different configuration of these parameters has to be achieved in designing Solar Sustainable Housing. On Northern Latitudes, where “heating is the dominant requirement” following strategies can be effective: Low surface to volume ratio; maximising solar gain; reduction of the surface area facing north, or exposed to prevailing wind; insulation of building envelope; control of ventilation and infiltration; use of draught lobbies to separate heated spaces from the unheated spaces and from the outside; location of the entrance door away from corner and from prevailing wind; use “buffer spaces” on northern or exposed facades, unheated conservatories of “sunsspaces” on the south. On Southern Latitudes, where “cooling” is the dominant need following strategies may apply: Minimising solar gain; reduction of the surface area facing south; provision of overhangs, arcades, shutters and canopies to shade building envelope; use of ventilated walls and roofs; insulation of building envelope, particularly the roof; control of ventilation; provision of solar chimneys to encourage stack ventilation; location of openings on shaded side of building or so as to catch prevailing winds; use “buffer spaces” on southern facades; use of strategy of passive cooling system: ventilation, night-sky radiation, evaporative cooling; use of “courtyards” to form reservoir of cool air close to building and introduce daylight to deep building plans and open spaces to prevailing wind (J&James 1999)

For an efficient and thermal comfort of the buildings in warm climates, importance has to be given to summer cooling more than winter heating or in the same entity, while the role of natural ventilation and day lighting become fundamental. An important issue assumes the relationship between buildings and the external spaces in a different scale organization from the building to the district and to the City as a hole.

2. MEDITERRANEAN CLIMATE

“Bioclimatic Housing – innovative design for warm climate” J&James 2007 is the result of the work of the “International Cooling Group” from Iran, Malaysia, Australia, Japan and Italy under the auspices of a 5 year IEA SHC project on “Solar Sustainable Housing” Mediterranean climate and the new “urban comfort planning case study” at Umbertide, designed for the Ecocity EU
Programme, was the Italian contribution.

2.1 Mediterranean Climatic context

“What is Mediterranean? Thousands of things together: Not a landscape but innumerable landscapes. Not a sea but a sequence of seas. Not a civilization but a set of civilizations build side by side. Travelling in Mediterranean means meeting the Roman world in Lebanon, prehistory in Sardinia, Greek cities in Sicily, the Arabian presence in Spain, Turkish Islam in Yugoslavia. The orographic and climatic characteristics of the Mediterranean originate from an historical complex and geopolitical evolution that left us important common historical and cultural roots. The fundamental unifying basis of the Mediterranean zone is the “climate”, which brings landscapes and societies... closer together” (Braudel, 1987).

The Mediterranean climate is experienced by those countries bordering the Mediterranean Sea. It is usually experienced between 30 to 50 degrees north and 30 to 40 degrees south of the Equator. Other areas of the world have Mediterranean-type climates; these climates can be assumed as “climatic typology” characterized through their location and local weather patterns. A number of climate zones can be distinguished in the European region. The Köppen classification defines: 1) Mediterranean coastal zone < 22°C in temperature; and 2) Atlantic coastal zone: Portugal–Morocco > 22°C in temperature. The average standard Mediterranean climate, however, is determined both by south tropical air and North Pole cold currents. The mean useful cooling energy for horizontal surfaces facing the sky factor is approximately 7Whm2. Daily global irradiation decreases with increasing latitude; but in January this trend is more pronounced than in June. Total diffused solar radiation during June to September changes from 217KJ per cm2 to 308KJ per cm2 and comprises 41 to 47 per cent of the total annual value of direct solar radiation. The direct solar radiation’s annual medium values are 35 to 44 per cent of the global radiation. In the Mediterranean area, is a heating demand in the winter, but cooling is necessary during the summer. Wind is present everywhere. The effect of wind direction and wind speed on heating and cooling requirements depends upon the outdoor temperature and upon solar radiation. Cold northerly and easterly wind can, for instance, have more effect on heating requirements than the more frequently occurring gentle south-western wind. The annual average frequency of the wind direction illustrates that the wind can blow from any direction, with a dominant direction in some locations. In the southern half Europe, interactions between mountains, warmer seas and hot deserts to the south of the Mediterranean produce many well-identified local winds, such as the Mistral, a strong down-slope northerly wind, which penetrates the Rhone Valley and spreads along the French Riviera to the Mediterranean sea for long periods in winter. Another such wind is the Sirocco, which brings air masses from the Sahara into Southern Europe. High wind values can be registered on the east side of the Mediterranean area: 6.6 metres per second in Skiros (Greece) and 2.2 metres per second in Palma de Majorca (Spain).

Figure 1: Principle winds of the Mediterranean Area

2.2 Italian climate and orographic system

The orographic, hydro-graphic and geopolitical structure of Italy is mainly based on two important territorial systems. The first coincides transversally with the Alps and the Po River. The second coincides longitudinally with the Apennine Mountains and its main systems of rivers and valleys, the Arno-Chiana-Tevere, Tevere-Metauro and the Sacco-Gargiliano-Volturno. This second system divides the central part of Italy into two longitudinal halves, one along the Tyrrhenian Sea and one along the Adriatic Sea, each with different historical and cultural roots. The “Umbria Region” is situated in the very heart of Italy, on the Arno-Chiana-Tevere River system, and is surrounded by important regions such as Toscana, Marche and Lazio. The region covers three valleys, the Nerina Valley on the River Nera; the Umbria Valley on Clitunno and the Alta Valle del Tevere, north of the Umbria Valley, with its separate characteristics of a specialized local economy.

3. ECOCITY PROJECT – “URBAN COMFORT” AS CITY PLANNING DESIGN

Following the new Municipality General Master Plan and the results of the Citizens’ Community Planning”, general guidelines for the Urban Renewal Master Plan for the Umbertide case study were established, with the eco-city concepts agreement: “City as a Renewable Energies Power Station”, Car Free City, Bio-climatic Comfort City, Cultural Identity and Social Diversity.
The site analysis originates from the philosophy regarding the “studies for the city” that has represented the Italian contribution, from the year ‘50 on, to the resumption of the historical centers. This recognized the city and the territory as a long-life holistic organism typology in a constant evolution process, in use, technology and form. As a logical continuation of this philosophy, the project promotes the use, reuse and reinvigoration of cultural heritage, and supports continuity of the urban cultural identity at different levels. History, microclimate, urban grain and building typology are the main matrixes for the city design. As Microclimate: the City of Umbertide is situated in the middle of the Alta Valle del Tevere, she lies in a temperate climate with rainy winters and hot summers, 2192 degree day, annual average sun radiation of 3.93kW/m2/day winter 1.75kW/m2/day; summer 6.11kW/m2/day. During the summer months, light breezes from 5 to 10 m/sec. from the south, east or west enter the city from the surrounding hills and are caught by the streets, that separate the buildings, providing them with natural air conditioning. During the remaining seasonal periods the prevalent direction of the wind is north/west. The maximum values of the solar radiation are in the central period of the year, with 22.9MJ/m2 in June and 23.3MJ/mq in July; the minimum value are in December, with 5.1MJ/mq, and in January, with 5.6MJ/mq. Minimum temperature values occur in December and January, with 1.2°C and –0.9°C, and maximum temperatures occur in July and August, with 27.7°C and 30.9°C. The city and landscape “Urban Grain” morphology derives from the geometry of the ancient “Roman centuriatio”, still visible in the flat area around the Tiberina road, organized along the sun and wind directions.. The urban structure was also planned in accordance with the “water system”, in function of its collection, distribution and drainage. The water, green and the landscape network, all oriented towards the sun and the wind, are responsive to both the ancient and the modern city. From the urban grain the analysis continues to Urban Texture and Building Typology, concentrating on the Italic “casa corte” as a local interpretation of the “Roman domus”. Such typology, within its perimeters, gradually articulates its buildings around two fundamental systems. First the “Atrium”, a more architectural and defined space serving as “Impluvium” for rain water storage, the second the “Peristilium”, a larger and more open space used as a vegetable garden. Such systems, not only represent the most suitable technological answer to more compact urban aggregation of the high density city, but also represent the more efficient “bioclimatic mechanism”. The site, as the last available development area of the city, does not present the most suitable microclimatic condition. The project worked deeply to gain maximum comfort from the existing microclimate. The “citizen's well being” target aims to transform the area through a series of urban measures in order to obtain bioclimatic benefits, the mitigation of emissions and the control of air and noise. This has been called “urban comfort” and assumed as the principal motivation for urban design and for the new sustainable transport structure. The first objective was to build the “bearing skeleton” of the urban structure by the ventilation oriented main axis, coming from the hillside over the river, in strict accordance with the existing city’s oriented frame. Consequently the “Bioclimatic Principal Spine” tunnels the wind from the river park, from the south, to the railway station and the ninth century city. The “Historical Bioclimatic Spine” tunnels the wind from the new urban area A to the ancient Borgo Minore, and the other two remaining “wind corridors” run from the area B through the existing oriented roads of the “Workmen Village”, and the modern city.

At the building level, microclimates have been created that are responsive to urban texture and building typologies. The design of the urban texture is constituted by a system of buildings aggregated around a common external “corte” derived from the ancient “Roman domus”. The alternance of form and function of this external space is organized depending on the position of the site, in correspondence of the pedestrian main wind axis or to the secondary alignments of the “edible gardens” in two different “urban texture typologies”: The first organized in “Case Corti - Atrium blocks” and the second in “Case Corti - Atrium and Peristilium blocks”; each with three different “building typologies”: Apartments, Detached House or Row House.
3.1 Natural Ventilation System

The urban planning project has been designed improving ventilation in local neighbourhoods and housing clusters. This has been achieved by harnessing the prevailing direction of the wind during the various seasons. Further techniques have been used to obtain protection from winter wind (rows of trees) and to promote summer wind penetration, with consequent reduction of energy demand for buildings. Urban natural ventilation system flows are tunnelled through the main wind-corridor pedestrian spines into the private ‘corte open spaces’ and the different buildings structures. At the building level, the system is based on the use of “three ventilation chimneys”: two for air admission and one for expulsion; during the night in summertime, because of the lower external air temperature, such chimneys produce air cooling of the chimneys and of the building structures through stack effect. In wintertime, solar radiation on the transparent part of the chimneys of the south façade generates a convective loop, which transfers the heat picked up from the masses of the inner chimneys to the rooms.

This simple and integrated bioclimatic system is able to obtain a high energy performance that improves the quality of the indoor and outdoor microclimate. This system provides completely natural ventilation and is an innovative choice for the project. The consequences for the design and the structure of the building are:

- for the Urban consequence, the shape and configuration of both the buildings and the public and private open spaces derives directly from ventilation requirements; in fact, the disposition of each courtyard and of the surrounding blocks, and the selection of their heights, depend upon wind corridors. In this way, it is possible to guarantee a satisfactory degree of wind penetration in summertime when the wind comes from the south. On the other hand, a barrier against winter winds with rows of trees, has been planned for the northern part of the site, along the railway track.

- for the Building effects, the southern façade of each building requires specific treatment in order to provide places for air channels and brise-soleil; a similar problem has been faced in positioning air vents and chimneys appropriately with respect to the distribution of rooms. The heat accumulated in the mass of the chimneys will be used during the night to heat rooms and for ventilation. In this way, the system controls air changes, as well as temperatures, in all seasonal conditions.

3.3 Planning Tools Applied

The whole project has been tested and improved through continuous fluid dynamic software simulations (Fluent). At the urban level, several simulations with Fluent (fluid dynamic model simulations) have been carried out to estimate the effects of the wind in order to improve summer ventilation conditions. Reference data for the simulation comprised a wind speed of 5m/sec.; simulation was completed for the whole intervention area, also calculating speed and pressure. Due to the results of such simulations, it was able to determine the courtyard shape and the bioclimatic corridors to obtain an optimized disposition of the single buildings in order to create sufficient and comfortable ventilation for both external and internal areas. At the “building level,” the use of the stack effect, integrated with a convective loop system and with a chimney to realize a system of cooling and ventilation resulted in a good microclimate and adequate indoor conditions during summertime.

3.4 Building Health and Well-Being

Unlike “conventional urban planning”, structured
along roads for cars, this project, almost completely “car free”, is organized according to bioclimatic wind tunnel axis, overlapped by pedestrian and cycling paths. Alternative mobility is the “real core” of the urban renewal project; in fact it provides the “main axis of the urban structure design” for both pedestrian and cycling street circulation framework and public, semi-public and private open space architecture. Alternative mobility become the “prominent feature” of the project, divided into different typologies related to fast and slow mode, or to interrelation issues, such as “single minded spaces”, or “open minded spaces”, organized according not only to “urban comfort” issues and urban design, but also to high parameters of aesthetic and attractiveness quality in order to make them more pleasant and integrated for public “fruibility”. They were organized along the north/south bioclimatic spine and the wind corridors between the urban and building cavities, the alternation of the private and semi-public courtyards, the public square and the mixed use polarities, the “urban green salotto” where the comfort and the aesthetic quality have been optimized. The use of green zones, ponds, brooks and canals combines with the evaporative transpiration effect of the vegetation to improve the conditions of the local microclimate and to reduce the energy demand of the buildings. The housing energy target refers to the Italian Casa Clima Category A Plus, with a 20/15kWh/m²/year A biomass district heating plant designed by experts and citizens involved in a participation process, for a thermal energy demand of 679.160 kWh/y. The energy saving reached is 75% and the carbon dioxide (CO2) emission reduced is 73%.

Figure 6: Urban Ventilation Scheme

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