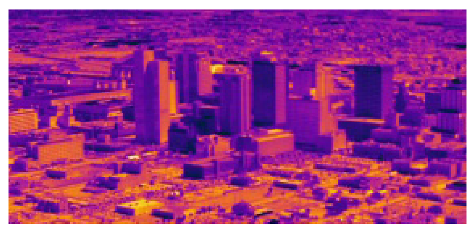
July 2, 2008

4 Sustainable Development in a Desert Climate

INTRODUCTION

This chapter of the Downtown Phoenix Plan provides an assessment of the conditions affecting the thermal comfort of pedestrians and the Urban Heat Island Effect in Downtown Phoenix Arizona. It also provides a set of principles, that may be implemented in the form of zoning standards and building code regulations that, when adopted, will create a more comfortable and sustainable downtown environment. It is based on an extensive year-long research project by Arizona State University (ASU) and the architectural firm Studio Ma.



Infrared camera image of downtown Phoenix. (Arizona Republic)

Thermal comfort is a key to the success of Downtown Phoenix. Extreme summer heat has resulted in stressful street level conditions in the Downtown area, to the extent that is has a negative impact on the development of a pedestrian-friendly, civic environment.

Acceptable levels of thermal comfort can be achieved in Downtown through an integrated approach to the design of the urban environment that includes street and building proportions, open space, urban forestry, building design and appropriate building materials.

One of the key aspects of the research is a consideration of the role of urban form, understood as the integrated design of streets and buildings, relative to issues of thermal comfort and the Urban Heat Island Effect (UHI). Despite the strong relationship between these two conditions, methods to improve thermal comfort are not always consistent with the methods needed to mitigate UHI.

PHOENIX CLIMATE

Located in the upper reaches of the Sonoran Desert Region, Phoenix has an arid, semitropical climate characterized by mild winters and extreme summer temperatures. Winter temperatures range from average lows of 42°F of average highs of 66°F while summer temperatures range from average lows of 81°F to average highs of 106°F. The average humidity levels are low allowing for greater levels of comfort at higher temperatures, however the heat of the late summer months is exacerbated by higher humidity levels due moisture drawn up from the Gulfs of Mexico and California.

The extreme summer heat is further increased by the UHI, a phenomena of increased temperatures relative to surrounding rural areas due to the presence of high mass paving and building structures. This effect is most pronounced in highly developed areas such Downtown Phoenix where evening temperatures have increased 12°F over the past 40 years.

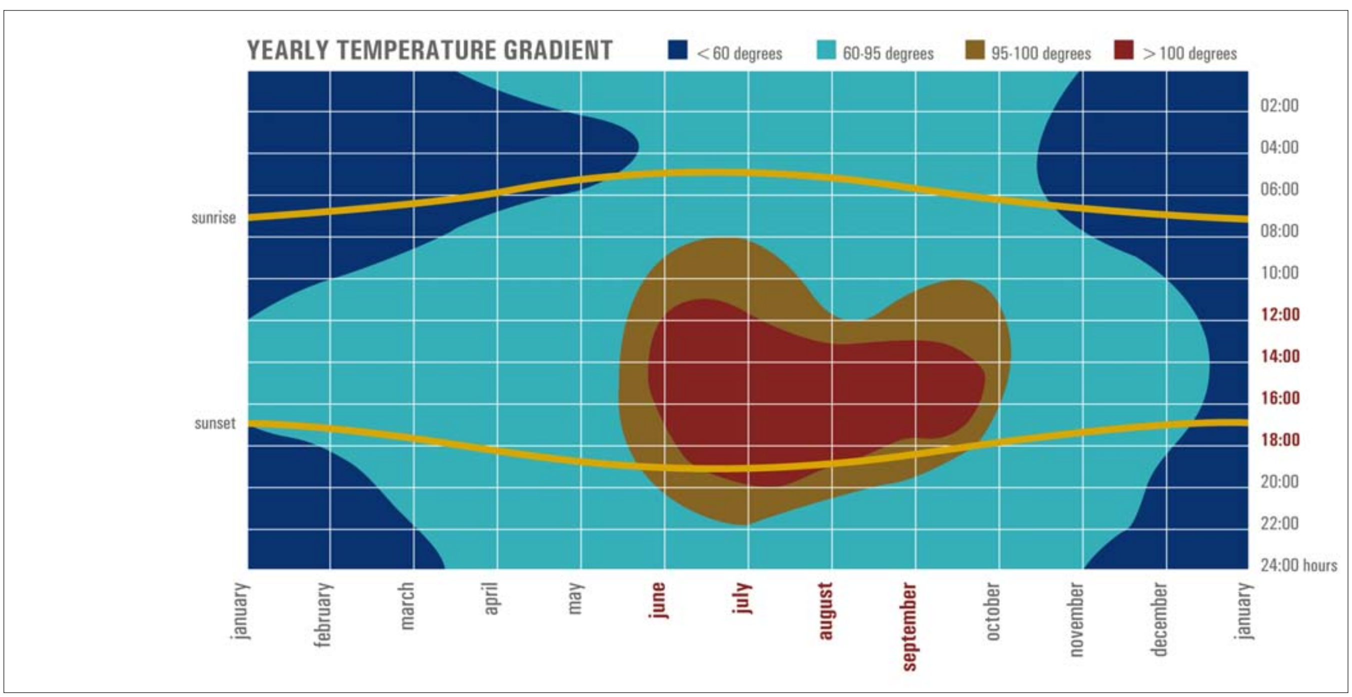


FIGURE 4-1 YEARLY TEMPERATURE GRADIENT

Average daytime temperatures have not increased appreciably over the same period but the effects of lingering evening heat are noticeable.

The yearly temperature gradient chart (Figure 4-1) indicates the time period for the amount of comfort hours per day based on average air temperatures for the region. Due to excessive heat buildup in the Downtown area, the comfort contour has been reduced up to 15%. The preparation of sustainability development standards should The goal of the proposed standards is to maintain the existing contour while improving it significantly in certain specific areas.

THERMAL COMFORT: HUMAN-ENVIRONMENT HEAT BALANCE

The Human-Environment Heat Balance is dependent on a number of factors, key of which is the maintenance of a balance between the heat produced by the body through its natural metabolism (approximately 400 BTU/HR for a normal adult) and the dissipation of this heat to the surrounding environment. If the environment is too cold, the heat from the body is lost faster than it can be produced. On the other hand, if the surrounding environment is too hot, the body will be overheated due to its inability to shed excess heat.

Shade is the first line of defense in an effective heat mitigation strategy for Phoenix. It prevents the rays of the sun from heating up the surrounding surfaces and can be produced by architectural features as well natural sources such as trees. Materials are the second line of defense. Put simply the denser and darker the material, the more heat it is able to retain and re-radiate to the surrounding environment. If materials are made lighter and more porous they retain and re-radiate smaller amounts of heat. Moisture and air movement are the third line of defense. The desert environment is very dry allowing water to evaporate easily which promotes cooling. Water is also cooler than the surrounding hard materials and absorbs a great deal of heat without an appreciable rise in temperature. Air movement promotes evaporation and can remove excess surface heat through convective flows.

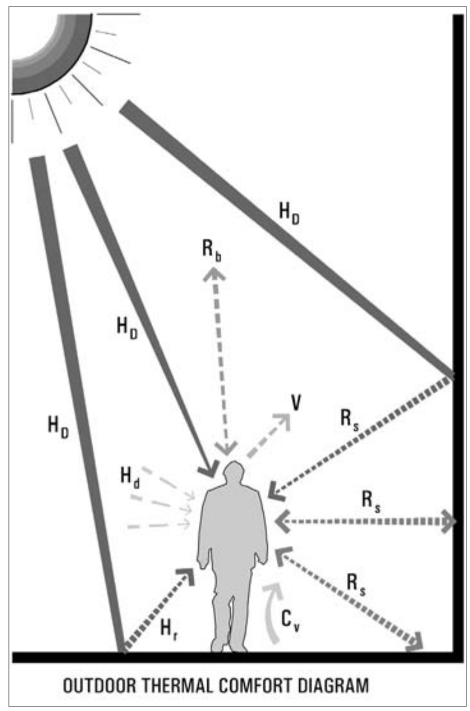
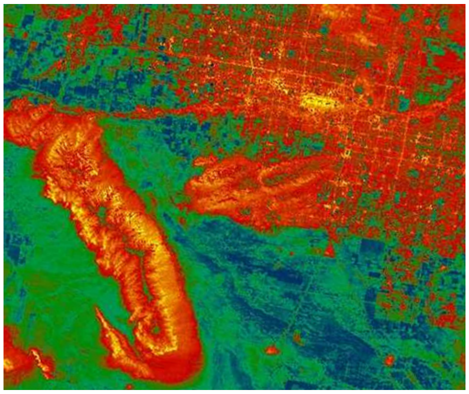


FIGURE 4-2 OUTDOOR BODILY-HEAT TRANSFER



Infrared image depicting the Phoenix Metropolitan area at night. The different colors depict the temperature variations across the valley, from the cool blue/green shades in the valley outskirts, to the hot red/yellow hues in the central part of the city. (ASU Geological Remote Sensing Laboratory)

Buildings, asphalt streets and parking lots act like heat sponges, soaking up the energy from sunlight. Then at night, they release all that heat.

URBAN HEAT ISLAND

Urban Heat Island is the temperature difference between densely populated urban areas and the surrounding countryside. This effect is most pronounced during evening hours and is due in large part to the increased thermal storage created by urban materials which, like concrete paving, tend to be dense and impervious to water. By replacing native vegetation with pavement, less moisture is absorbed by the ground and by plants resulting in the loss of evapotranspiration. Building materials are often darker than natural occurring materials and have a lower ability to reflect solar radiation back to the sky resulting in further increases in surface temperature. Additionally, but to a lesser extent is the introduction of anthropogenic heat which comes from heat being released from engines and mechanical cooling equipment.

Examining the Phoenix region over the 20th century, average annual temperature has increased 5.53°F but a rapid threefold increase has occurred in urban areas of the region. The .86°F/decade warming rate for Phoenix is one of the highest in the world for a population of its size and can be compared to other cities to highlight the effects of rapid urbanization in the region.

The US Climate Assessment conservatively projects that the Southwest will see a 5.4°F increase in mean annual temperatures by 2100. This increase is much higher than the 3.1°F increase in the last 70 years. Urban heat island increases are likely to be much higher in the coming decades than in the past.

Exactly where and how the local temperatures would increase depends upon climate system trends, urbanization rates, building materials and landscaping. Presently, the region's urban areas experience nighttime temperatures that are 12°F warmer the rural areas.

Even with moderate population growth, this temperature gap is expected to widen, with potential for a 15°F nighttime increase by 2030 in the urban area: 60 years from now, a 20°F increase; and by 2100, a 25°F increase. (Brazel, 2003)

BUILDING FORM AND SHADE

OVERVIEW

With its extreme summer temperatures, Phoenix poses unique challenges to pedestrian comfort. High daytime and evening temperatures combine to raise the temperature of the built environment with little opportunity to lower or "flush-out" the heat during the evening hours, hence the use of conventional air conditioning which consumes energy and adds heat to the outdoor environment.

In order to successfully address the problem an integrated approach is required that combines a wide range of factors including building and street proportions, architectural and natural shading, material properties, air movement, the appropriate use of water and psychological / physiological considerations.

A successful strategy should provide cooling during the summer months while also allowing the warming effect of the sun during the winter.

OPTIMIZING STREET CANYON PROPORTIONS FOR SHADE, SKY VIEW AND AIR FLOW

Dense urban environments present special opportunities and challenges with regard to heat mitigation. On the one hand, narrow streets lined with tall buildings provide shade from the sun, keeping the building mass relatively cool during the morning hours. This has been the historical approach taken to the planning of hot desert cities but contemporary conditions such as tall buildings, UHI, new building materials and air pollution present new conditions that require a re-consideration of the historical model.

A number of factors must be considered in determining the most effective combination of street and building proportions (street canyon) Phoenix. These include the amount of shade cast onto the street and other surface by buildings, the ability of heated building surface to release their heat to the evening sky, and the ability of air to move freely through the urban environment.

BUILDING FORM AND SHADING

Shade is the first consideration in mitigating excessive heat from the sun. When applied properly, shade from buildings can have a significant impact on thermal comfort and can also mitigate the overheating effects of UHI. Studies of traditional cities at the same latitude and climate as Phoenix show the prevalence of street canyon proportions of 1:3 (width to height) (Bourbia 2002). The narrower street canyon reduces the amount of direct sun hitting the sides of building walls and the street surfaces thereby reducing the amount of radiant heat absorbed by pedestrians during the day.

During the day the mass of buildings and streets accumulate radiant heat from the sun, releasing it to the sky during evening hours. Phoenix's dry desert climate allows the heat to escape, making night cooling one of the most effective methods of releasing accumulated heat. The rate of heat loss is diminished when the "sky view" available to the material is reduced, as in a narrow street canyon. In addition, the tall walls reflect the heat into the shaded areas increasing the total amount of heat trapped in the canyon. In other words, narrower streets are less effective in mitigating UHI. Much of this heat is absorbed by building mass and is released to the atmosphere during the evening hours.

The relationship between street canyon proportions, pedestrian comfort and Urban Heat Island (UHI) is demonstrated using computer simulation measuring the Meant Radiant Temperature (MRT) in a typical, high density urban environment. The simulation modeled three street canyon proportions for a twenty four hour period on June 21st. As can be seen the 1:1 street canyon proportion averaged 10°F hotter than the other proportions during the day and approximately 2.5°F between sunset and sunrise confirming the previously noted assumptions regarding the role of sky view in releasing heat during evening hours (refer to Figure 4-3). It is interesting to note that there is not a significant difference in performance between the 1:2 (mid rise) and 1:3 (high rise) proportions. One can conclude from this simulation that a street canyon proportion of 1:2 balances thermal comfort and UHI, providing a cooler pedestrian environment during the day while permitting an acceptable amount of heat release during evening hours.

The simulation along a north-south street produces similar results. However, note how the temperature spikes over a shorter period of time during the day resulting is less overall heat accumulation in the street cavity. Note also the distinct temperature differentiation between the three street canyon proportions confirming that narrower street canyon proportions have a direct impact on pedestrian comfort along the north-south axis (refer to Figures 4-4 and 4-5).

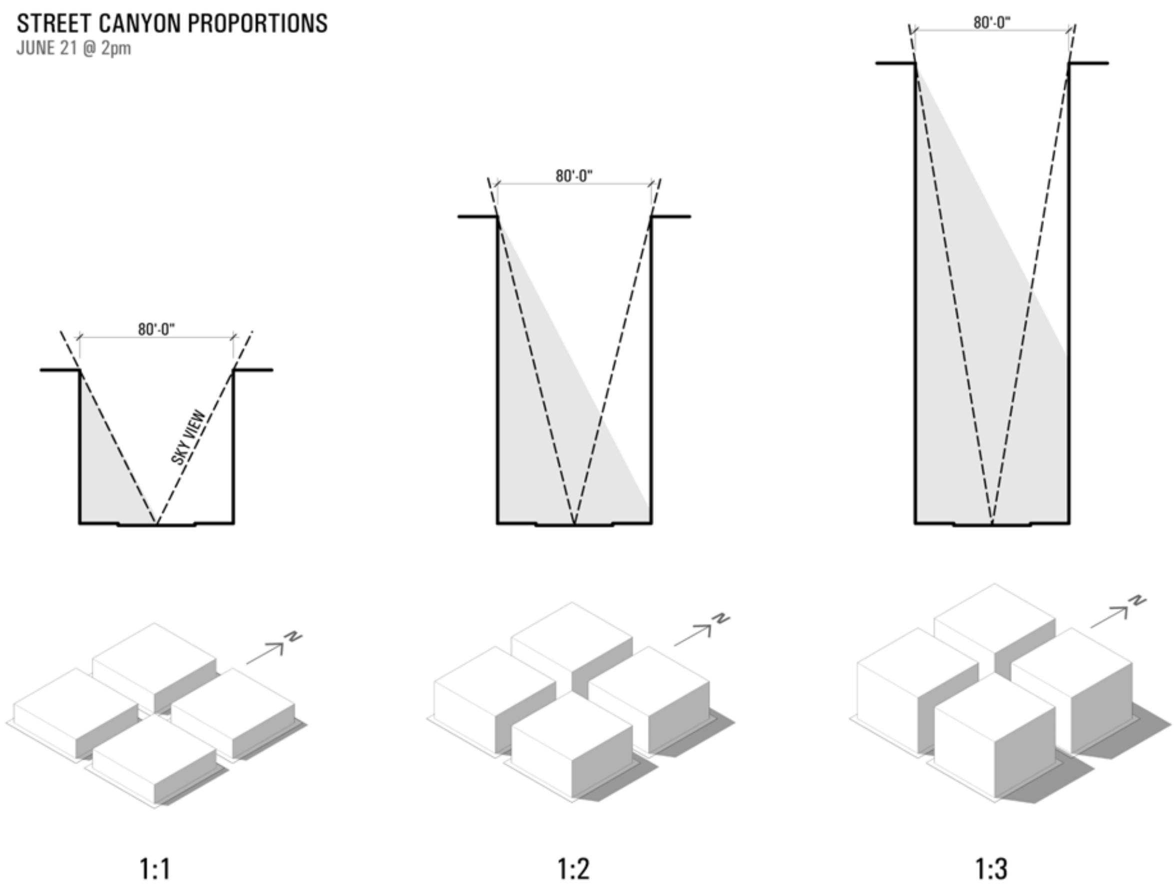


FIGURE 4-3 STREET CANYON PROPORTIONS AND SKY VIEW

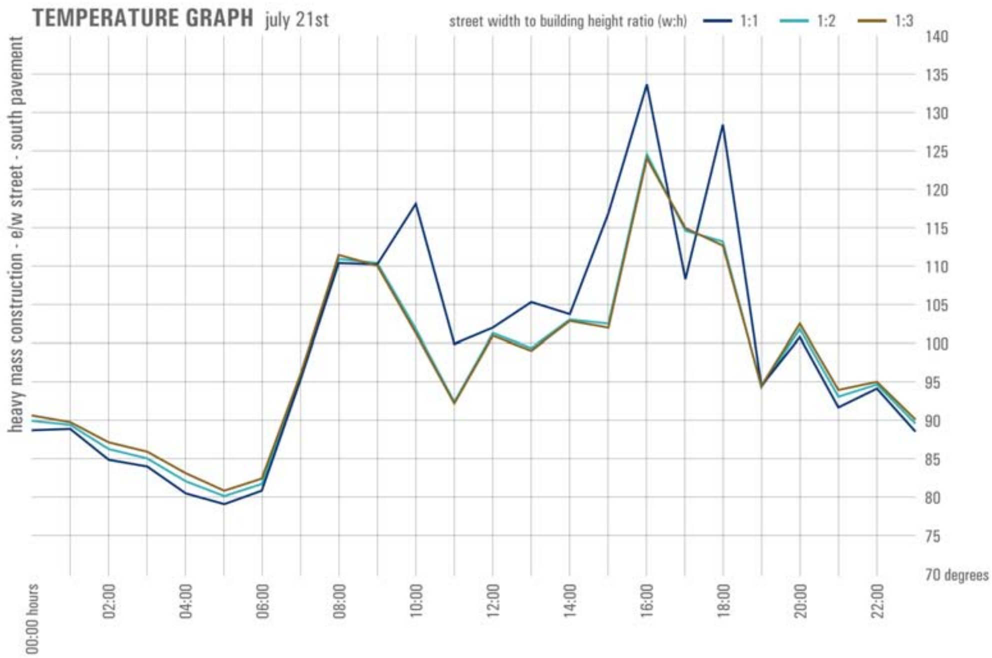


FIGURE 4-4 TEMPERATURE GRAPH, STREET WIDTH TO BUILDING HEIGHT RATIO, EAST–WEST STREET, SOUTH PAVEMENT

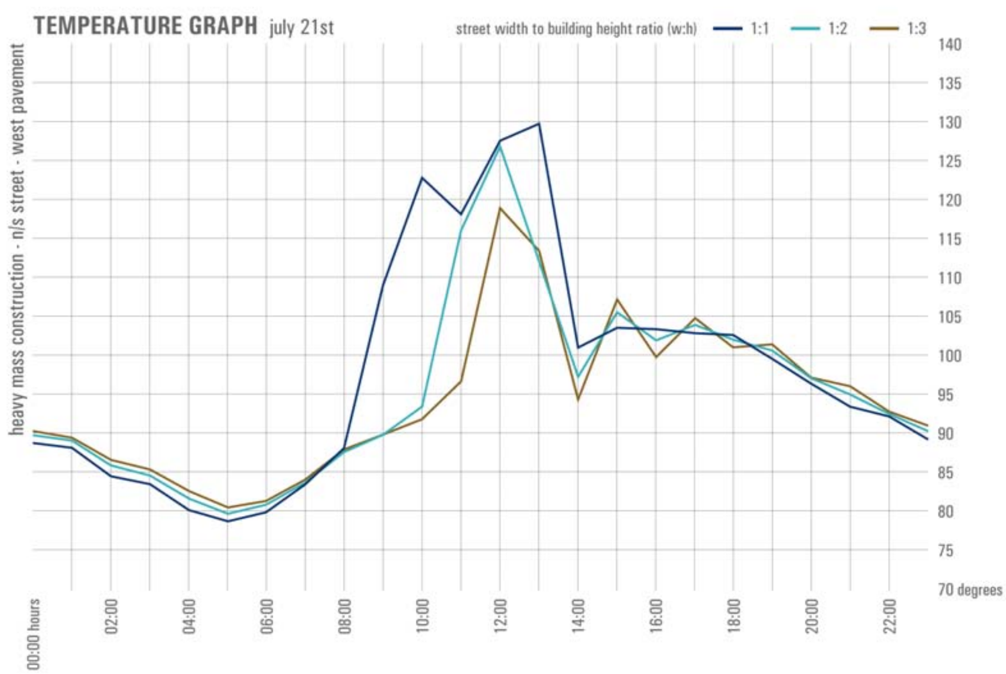


FIGURE 4-5 TEMPERATURE GRAPH, STREET WIDTH TO BUILDING HEIGHT RATIO, NORTH-SOUTH STREET, WEST PAVEMENT

BUILDING FORM AND AIRFLOW

Airflow is another significant factor from both a thermal comfort and UHI perspective. In an overheated environment, small amounts of airflow induce evaporative cooling from perspiration and is a major factor to perceived levels of comfort. In the evenings, buildings designed with adequate cross ventilation can remove heat and cool down the interior mass, reducing the need for mechanical cooling during the day. At certain times of the year wind can play a critical role in removing the excess heat that accumulates in a street canyon, thereby reducing UHI levels.

Reductions in UHI of .625°F for every increase in wind speed of 1 mile per hour have been noted in Melbourne Australia when wind speeds exceed 5 miles per hour. (Morris 2001). The average, yearly wind speed for Phoenix is 6.2 miles per hour, with the greatest sustained speeds occurring in the later afternoon flowing from west to east. As noted previously, the outdoor comfort zone for Downtown Phoenix is significantly diminished due to the presence of overheated materials in the environment. This condition is worsened in areas that do no receive airflow due to wind.

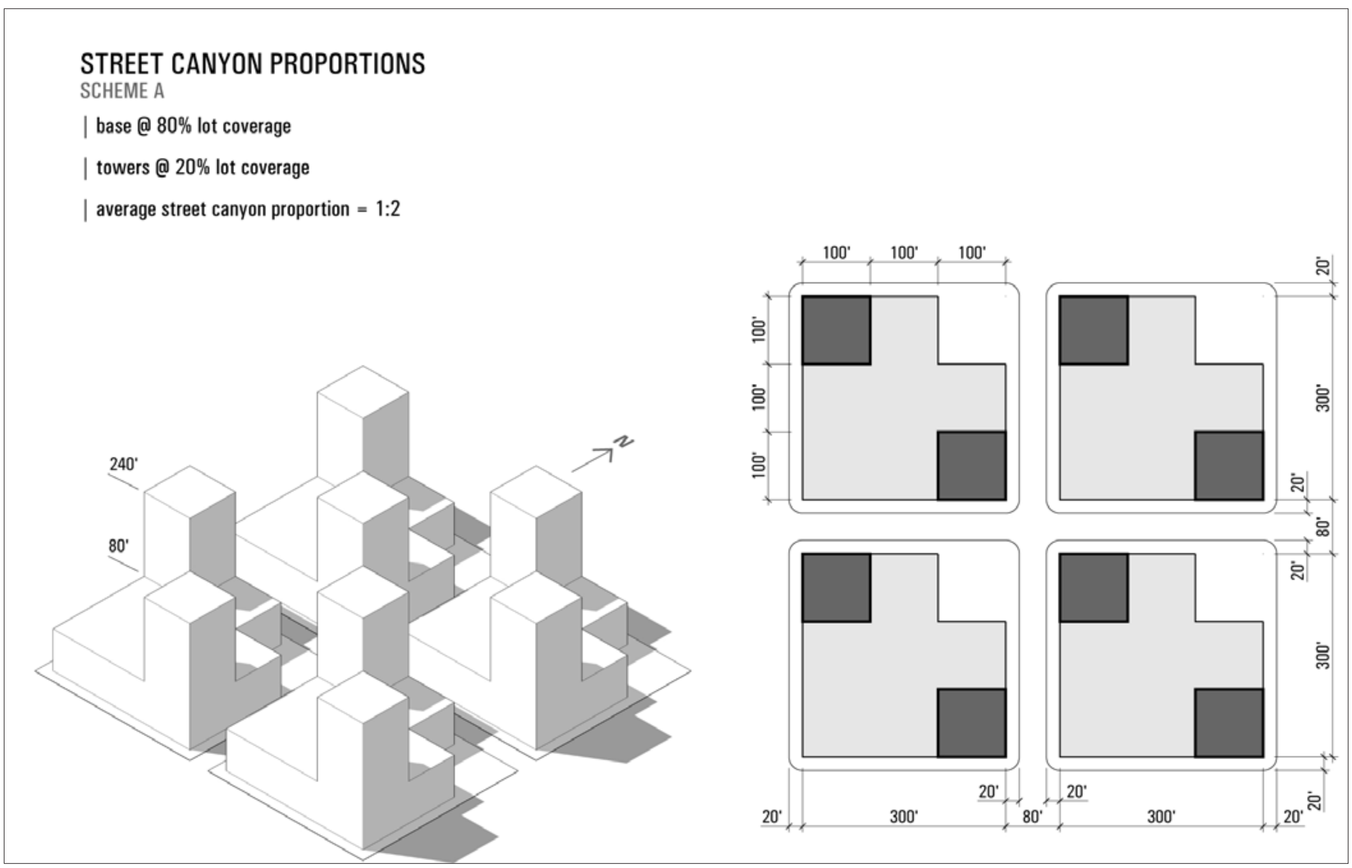


FIGURE 4-6 PROPOSED MASSING DIAGRAM

POLLUTION IN STREET CANYONS

Air-born pollutants accumulate in the urban canopy layer and rely upon an effective airflow to be "flushed out" and removed. Products of internal combustion engines, Carbon Monoxide and Nitrous Oxide accumulate in dense urban canyons. Along with dust and diesel emissions, this forms the background pollution found in most dense urban streets. Studies conducted in Europe (Mazzeo 2006) indicate that pollution levels increase in a 1:1 street canyon when wind speeds fall below five miles an hour due to the lack of sufficient vertical circulation in the street canyon.

Narrow streets and large buildings perpendicular to the direction of airflow restrict the movement of air, directing it up and over the built up urban area known as the "urban canopy layer." Studies indicate that a 1:1 street canyon proportion is at the lower end of the threshold for effective wind ventilation with the ideal width to height proportion

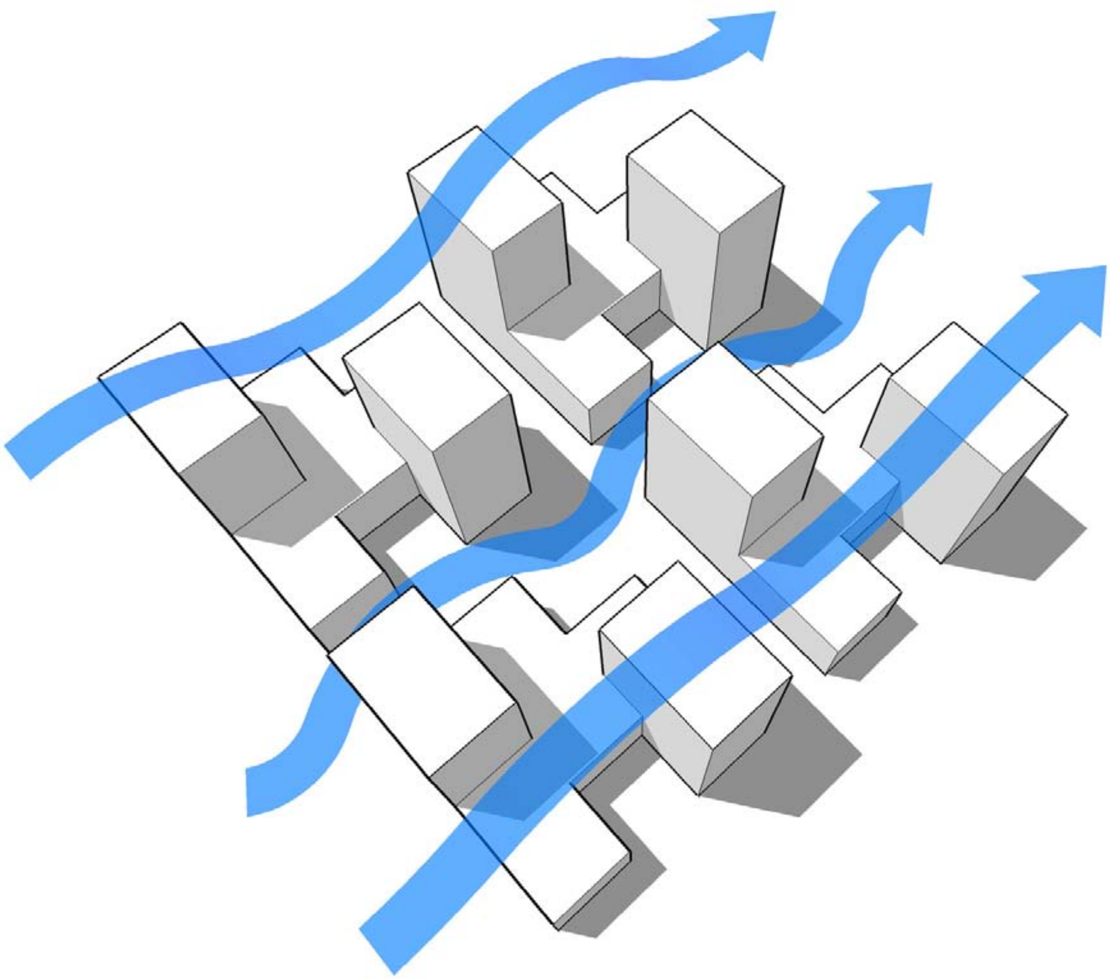


FIGURE 4-7 ILLUSTRATION OF OPTIMUM CANOPY LAYER AIRFLOW

being .65 (Oke 1988). In addition, streets arrange as long channels perpendicular to the wind, while allowing effective flow, do not produce sufficient turbulence to flush out particulate from the street canyon.

Increased turbulence and vertical flow is produced when the wind is permitted to flow through open channels roughened by the removal of significant portions of the street wall volume, including entire blocks. Additional turbulence is produced by the location of diagonally placed towers at the corners of the blocks.

These conditions are demonstrated in the following EnvironMet simulation measuring air speed through a base case scenario street canyon of 1:1 proportions. A variety of scenarios were examined where slabs and towers were added to the 1:1 base. Additional scenarios include "roughening" the street canyon through the removal of entire blocks and corners. The simulations were run on the evening of June 21 with wind flowing from the southwest. As can be seen, optimal results were achieved with diagonally placed towers on a base notched at the north east corner.

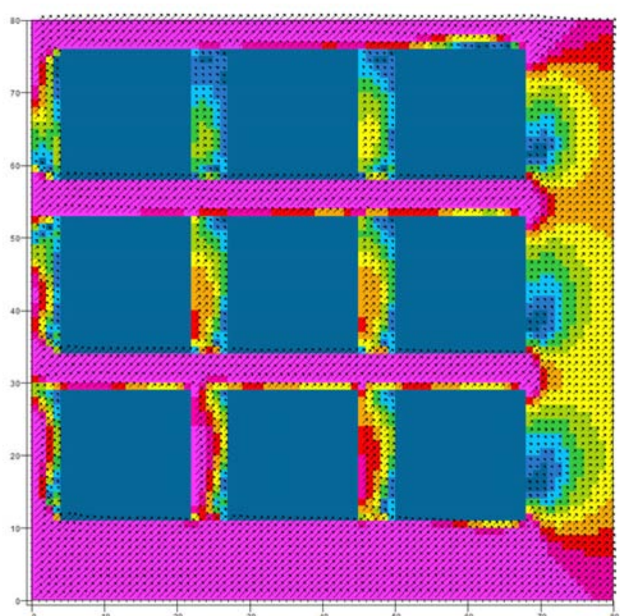


FIGURE 4-8 EFFECT OF GEOMETRY ON WIND SPEED IN THE URBAN CANOPY LAYER – BASE CASE

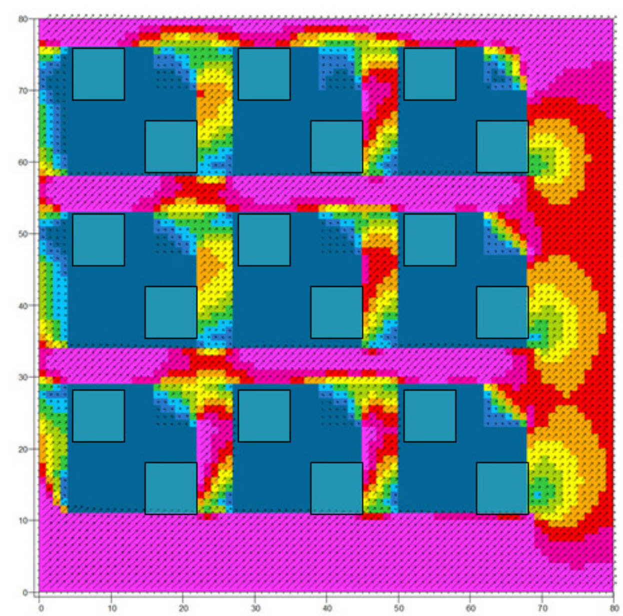


FIGURE 4-9 EFFECT OF GEOMETRY ON WIND SPEED IN THE URBAN CANOPY LAYER – CORNER NOTCHES AND DIAGONAL TOWERS

BUILDING FORM OPTIMIZATION AND PROPOSED MASSING STANDARDS

BUILDING FORM

Development standards should optimize building form to achieve comfort and sustainable development in the Phoenix climate. The standards should relate to building massing, street walls, and public spaces for high-rise commercial and residential districts, and produce the minimum required street level shading while allowing for appropriate levels of sky view and air circulation. Tower placement and open space erosion of the base block creates passages for wind movement in the east-west direction as well as creating turbulence within the urban canopy layer. This movement enhances heat exchange and the removal of air pollution.

The distribution of the open space enhances air movement through natural cross-ventilation, reducing the need for air-conditioning in spaces with operable windows and providing air movement for pedestrian comfort. Distributed open space creates spatial variety in the urban environment and can be enhanced through the development of porticoes, pocket parks, courtyards and through-block connectors. A number of large Downtown developments such as Renaissance Center and the Wells Fargo Center have used these features to create a pleasant pedestrian network linking City Hall to the Convention Center. The proposed urban form standards are designed to continue and enhance this type of development, and therefore contribute to the development of the Connected Oasis.

URBAN FORM MASSING STANDARDS

Given the assumptions and simulations noted above, the Urban Form Project is proposing the following building massing, street wall and open space guidelines for high rise commercial and residential districts should be considered when developing urban form standards:

- Maximum lot coverage of 80-90% (or 10-20% open space) not including alleys
- Building base not to exceed of 8 stories or 90'
- Building projections of 10' permitted in the right of way (creates effective street canyon proportion of 1:1.5)
- Maximum lot coverage of 50% above 8 story base
- Towers to be located a diagonally opposite corners
- The average street canyon proportion is not to exceed 1:2 – measured over the entire block (average of base and tower)
- Minimize building sections to encourage natural ventilation

Following these guidelines will result in the minimum required street level shading while also allowing for appropriate levels of sky view and air circulation. By limiting lot coverage as discussed will reduce the overall proportion of building mass to open space to 50% which enhances air movement in the street canyon. The checkerboard tower placement and open space erosion of the base block creates passages for wind movement in the east-west direction as well as creating turbulence within the urban canopy layer which enhances heat exchange and the removal of air pollution. The distribution of the open space through the block also enhances air movement through natural, cross ventilation; thereby reducing the need for air-conditioning spaces with operable windows and providing air movement for pedestrian comfort. Distributed open space creates spatial variety in the urban environment and can be enhanced through the development of porticoes, pocket parks, courtyards and through-block connectors. A number of large Downtown developments such as Renaissance Center and the Wells Fargo Center have used these features to create a pleasant pedestrian network linking City Hall to the Convention Center. The proposed urban form guidance are designed to continue and enhance this type of development, connecting the core to other parts of Downtown.

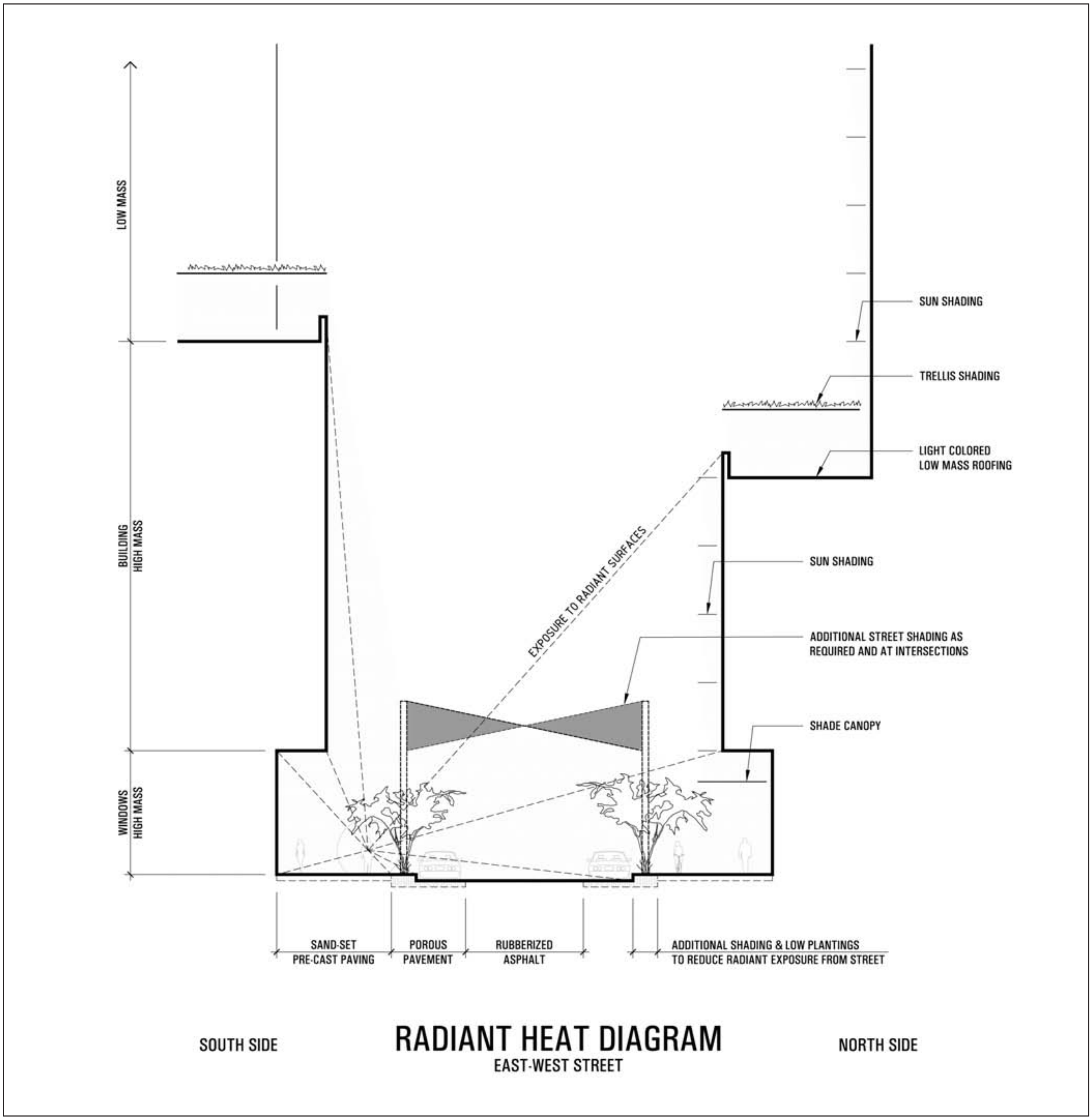


FIGURE 4-10 RADIANT HEAT DIAGRAM, EAST-WEST STREET

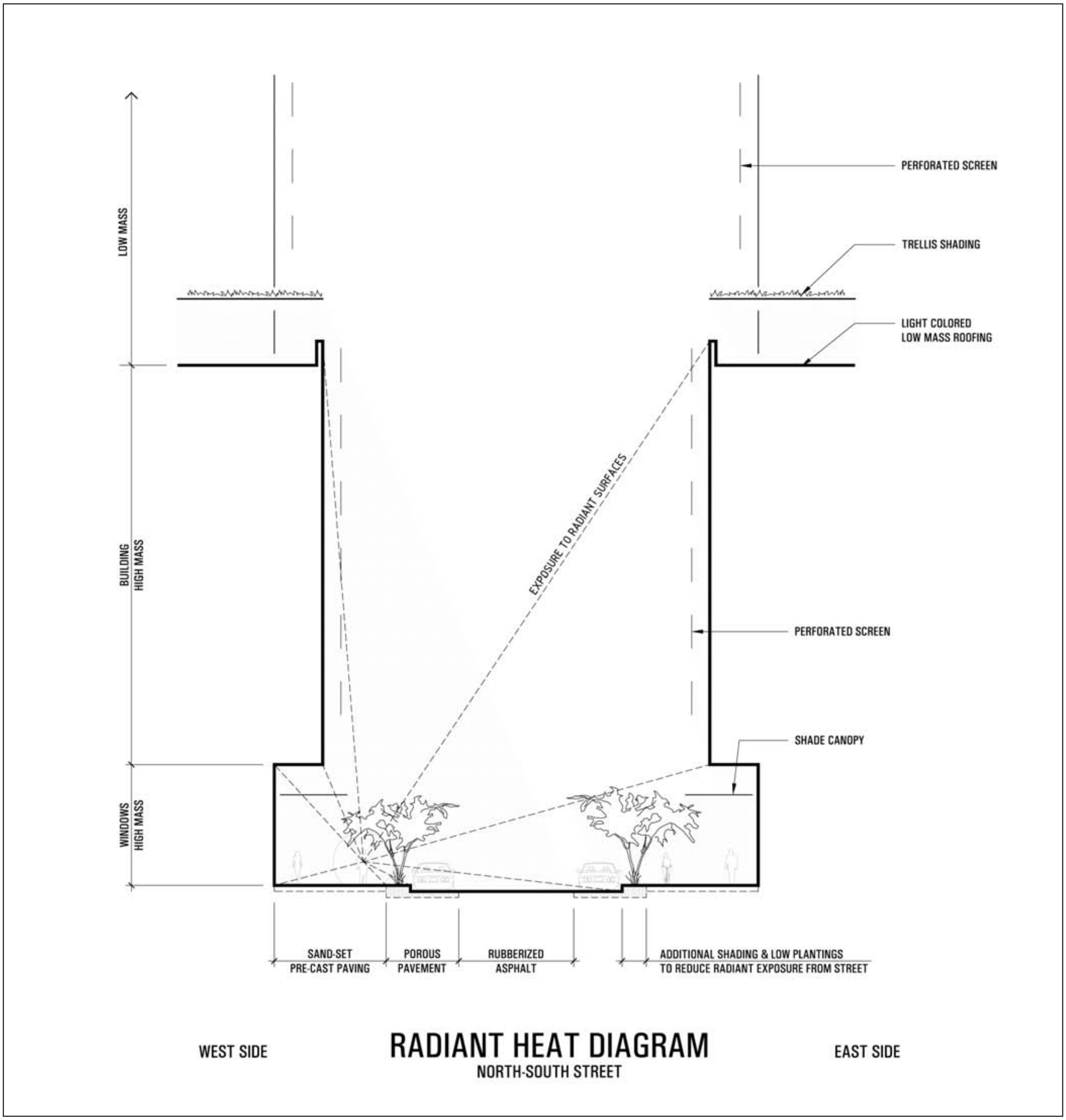


FIGURE 4-11 RADIANT HEAT DIAGRAM, NORTH-SOUTH STREET

SUPPLEMENTAL SHADING

Street Level Shading

The proposed street canyon proportions provide a minimum amount of shading coverage and must be supplemented by additional pedestrian-level shading on all street sides. This additional layer of shade shields pedestrians from the reflected light and long wave radiation from the structures above. The presence of a shade canopy (natural or architectural) also diminishes the amount of heat absorbed by the sidewalk and helps in the mitigation of UHI.

The Plan recommends that high density districts (including the Business Core) be provided with dense sidewalk shading in areas exposed to sunlight. Given the variety of street conditions in the Downtown area, the research presented here provides a "kit of parts" approach to street shading that includes options for a double row of trees, single rows, canopies, building overhangs and porticoes. Dense pedestrian and traffic areas should utilize architectural shading in addition to vertical screen walls accented with vines, trees and other plantings for protection against low sun angles and the heat emanating from adjacent streets and walls. On east-west streets, the north side of the street should be protected with canopies or porticoes while the south side can have less intensive pedestrian level shading due to the shade cast by the adjacent buildings.

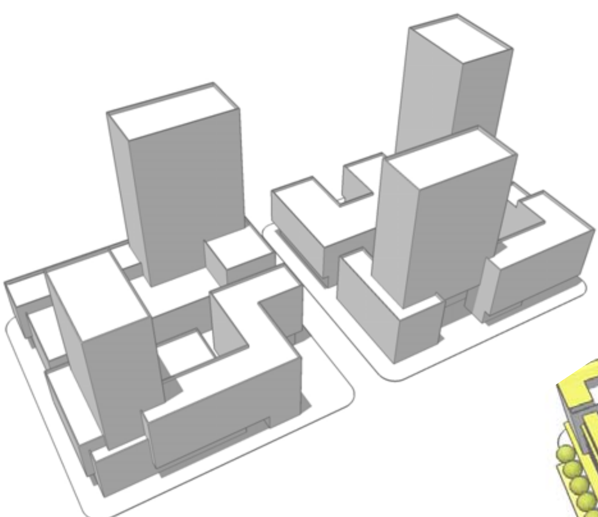


FIGURE 4-12 SHADING BASE CASE

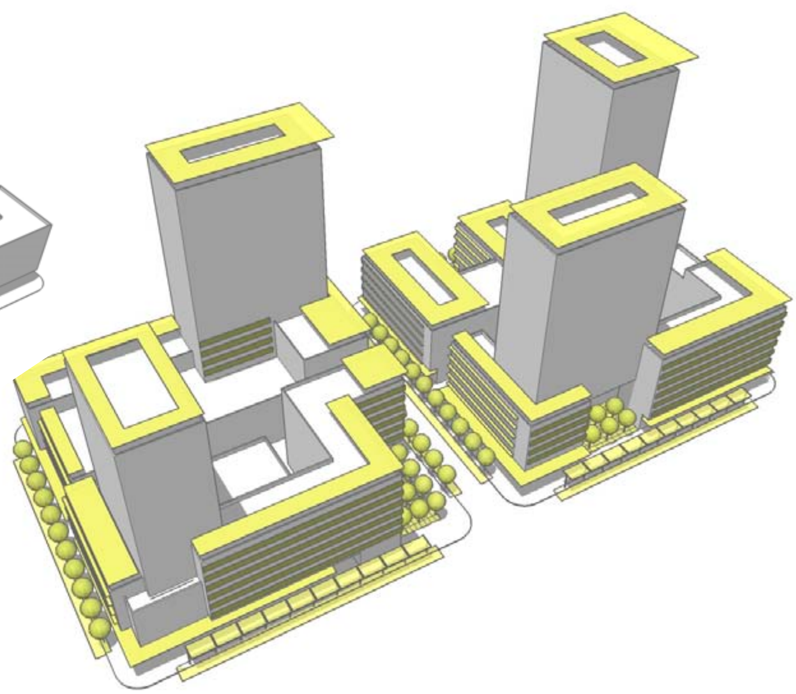


FIGURE 4-13 ILLUSTRATION OF SHADING STRATEGIES

In existing residential areas such as the Roosevelt District, the sidewalk is separated from the road by a substantial planting strip. Historically, the strip was planted with a single row of palm trees which do not provide enough shade during the summer months. Where possible the sidewalk should be flanked by a double row of shade trees. In addition the space between the street and sidewalk should be planted with low shrubs or screens to reduce exposure to the long wave radiation of the adjacent streets.

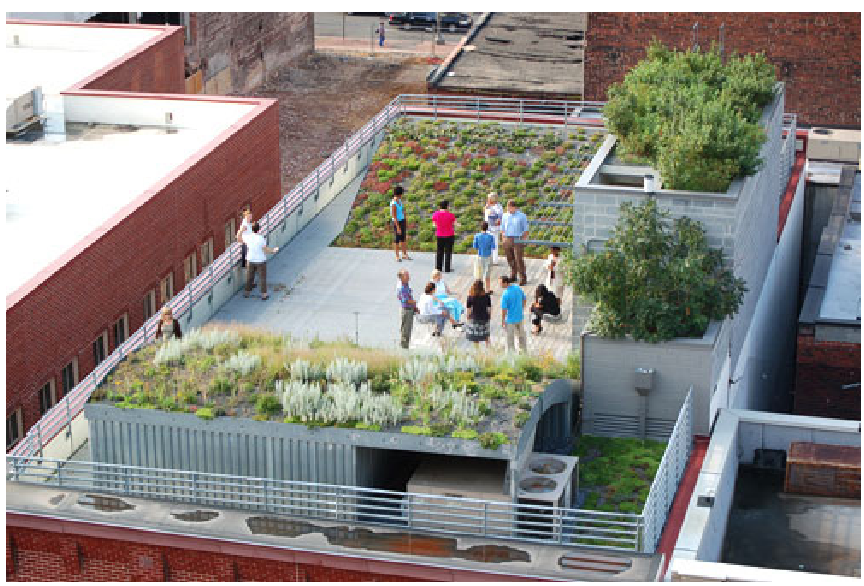
Second Avenue Streetscape project

Roof and Terrace Shading

Roof surfaces can have a significant impact on UHI. A variety of techniques have been used to reduce the amount of heat absorbed by the roof surface. These include high albedo (white) roofs, green roofs and green sky roofs. White roofs achieve their cooling effect by reflecting radiant energy off of the roof through the use of a white membrane. Green roofs are constructed with a layer of earth that supports a continuous vegetative cover. Cooling effects are produced from the shade of the plant materials evapotranspiration and the moisture of the soil..

The soil layer also acts as an insulating layer for the building below. A green sky roof is essentially a trellis supporting vines over an accessible roof surface. Each method has its own particular advantages and disadvantages from thermal comfort, UHI and practical perspectives.

Green sky roofs are most effective from a thermal comfort perspective, providing relatively cool temperatures between the surface of the roof and the shaded layer. Calculations of average air temperature for large sectors of Riyadh, Saudi Arabia (a city with a comparable climate) with a uniform roof type indicate that the green roof can lower the temperature approximately 2°F over a standard concrete paver type roofing, a green sky roof will lower the temperature by 1.5°F while a white roof will lower the temperature by 1°F.



ASLA Green Roof Demonstration Project

BUILDING MATERIALS

PAVING

As noted above, 40% of the building materials surrounding a pedestrian is made of a combination of sidewalk and street paving. Reductions in the amount of heat stored and transmitted by pavements also have a significant impact on pedestrian comfort and the UHI. The heat balance of pavements is affected by color, permeability, conductivity, mass and emissivity (the ability of objects to shed heat). In general, lighter colored materials with a relative low density are better at shedding radiant energy from the sun. Darker and denser materials are more effective at absorbing and holding heat. As an example, here in Arizona, the surface temperature of dark asphalt paving can be as high as 150° F on hot summer day while, lighter colored concrete will be approximately 122° F.

Thick and dense materials store a great deal of heat, releasing it into the air during the cooler evening hours. Heat stored in pavement is one of the major contributors to UHI, the mitigation of which can be achieved by using materials that are lighter and lower in density. A number of steps can be taken to reduce the amount of heat absorbed by paving materials. For example, recycled crumb rubber can be used as an aggregate in asphalt and concrete. Rubber is relatively low in density and is a poor conductor of heat resulting in lower surface temperatures during the day and less total heat stored during the evening hours.

Porous pavements such as porous asphalt, permeable concrete and open celled concrete pavers are less dense than standard concrete. While not as strong as standard concrete, these systems have the added benefit of being able to absorb and transmit air and moisture, providing a healthier environment for street trees.

WALL MATERIALS

The physical properties of wall materials also have an impact on pedestrian comfort and UHI. In general the thermal performance of building materials is "mainly determined by their optical and thermal characteristics, the albedo to solar radiation and their emissivity to long wave radiation are the most significant factors." (Doulos 2004) So called "cold materials" are characterized by a high reflectivity factor to short wave radiation (direct sunlight) and their ability to release heat into the environment during the evening hours. Surface roughness is also a factor, where a material rough textures can be more the 15% warmer that the same material with a smooth texture. (Doulos 2004).

Thin, smooth and light colored cladding systems such as metal panels, fritted glass (to reduce reflectance and glare), hollow core clay tile and fiber reinforced concrete perform well in overheated environments if they are applied over a free flowing air space typical of a "rain screen" application, allowing excess heat to be released into the atmosphere rather than conducting through the wall to the building interior where it must be removed through mechanical means.

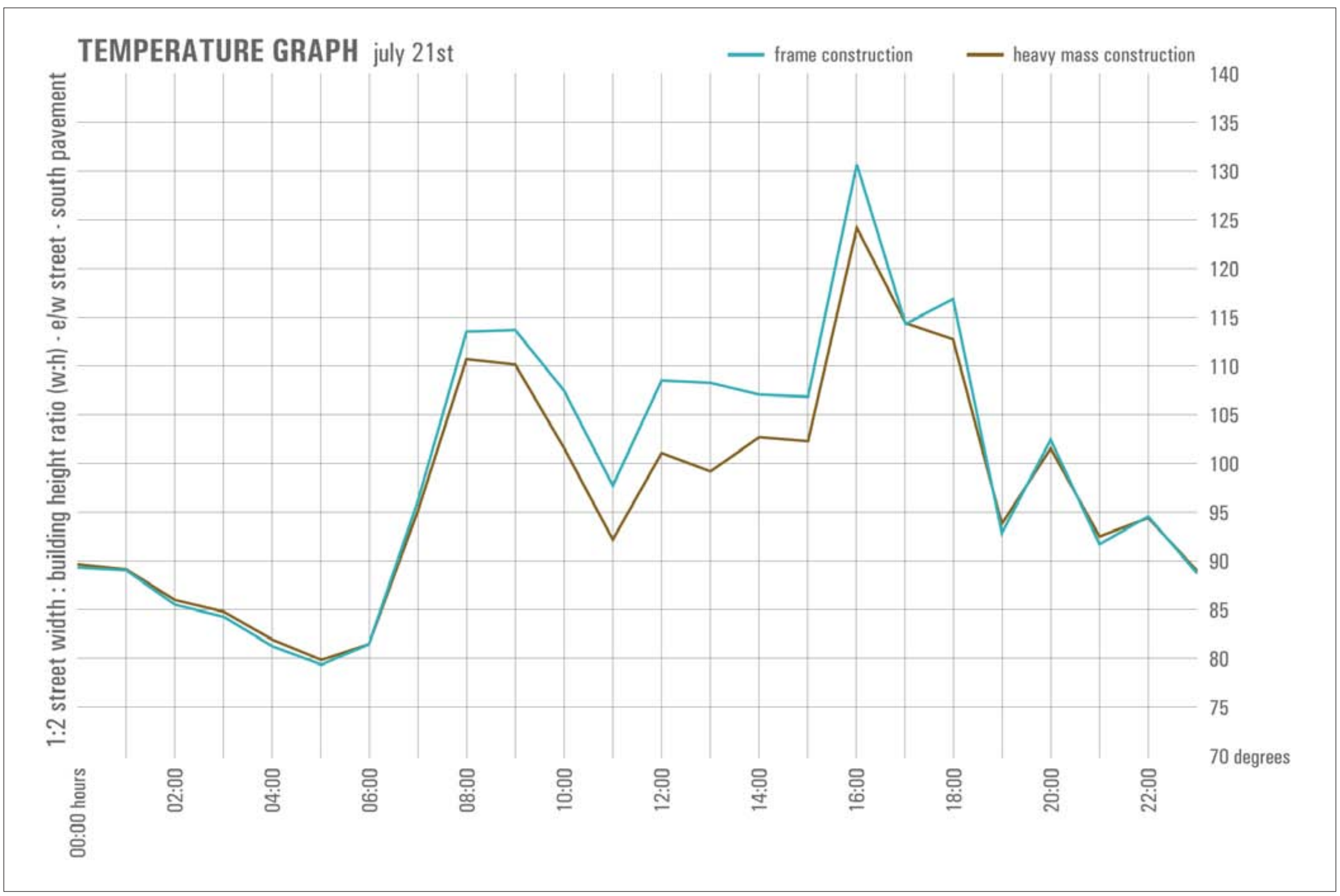


FIGURE 4-14 TEMPERATURE GRAPH, FRAME VS. HEAVY MASS CONSTRUCTION, EAST-WEST STREET

Commonly used Exterior Insulation and Finish Systems (EIFS) applications, where a thin coat of roughened plaster is applied over 1”-2” thick foam insulation, perform poorly under the direct rays of the sun but cool down during the evening hours. The surface temperature of dark colored EIFS application on the south facing wall at noon on the 21 of June in Phoenix with an air temperature of 100°F had a surface temperature of 120°F while an adjacent 4” thick light colored masonry wall had a surface temperature of 106°F. The relatively high surface temperature is due to the presence of the insulation near the surface preventing the heat from penetrating the wall and reflecting back to the surface.

Indirectly, Green Roofs and Walls reduce A/C requirements in buildings reducing energy consumption and heat production. (Musée du quai Branly, Paris, France)

Figure 4-14 on the opposite page compares the performance of a high mass and light mass frame walls on a sensor placed on the south sidewalk of an east west street. The light mass and high mass walls as similar to those described above. As can be seen, the high mass wall is an average of 7.5°F cooler than the light mass wall. This is due to the thermal lag effect whereby the radiant heat of the material is absorbed slowly over time, resulting in lower daytime temperatures.

When shaded from the sun, high mass walls will maintain a relatively low temperature and, if located near the pedestrian zone, will result in lower radiant and air temperatures. Light mass walls as described above are appropriate for use on towers above the street wall cavity.

Green walls can also be used for shading and induce cooling through evapotranspiration. This would be particularly effective as a way to screen and cool parking decks reducing the amount of heat buildup and storage during the daytime hours.

PSYCHOLOGICAL FACTORS

Psychological factors play a significant role in the perception of human comfort. Studies indicate these factors can contribute up to 15% of the perceived comfort level in a particular situation. In other words a space with an effective temperature of 100°F can be perceived as being up to 7.5° cooler or warmer depending upon the circumstances of the design. Major psychological comfort factors include “perceived control” defined as the ability to make choices of how one moves in a space, “variation,” or the availability of environments with different perceived temperatures and the “presence of nature” in the form of trees, planting and water. For example, a long passageway with solid, undifferentiated shade, while providing a lower temperature, will be perceived of as warmer than a passage with a variety of shading conditions just as a grove of trees producing thick dark shade will not be perceived as more comfortable that a grove that produces a dappled shade effect.

COOL POCKETS

Open space offers the opportunity to distribute “cool pockets” (areas of concentrated shading and cooling through the urban fabric). These spaces should utilize the full range of cooling strategies such as shading, low mass materials, evapotranspiration, the presence of water and air movement to reduce the SET on hot summer days to below 95 degrees. Densely planted plazas also function to cleanse the air in the immediate area of air born pollutants. Cool pockets should also be provided on a micro-planning scale for over exposed areas such as street corners and bus stops. The new bus stop design currently being considered by the City of Phoenix is a good first step and can be supplemented by small shelters, screens and canopies in other areas.

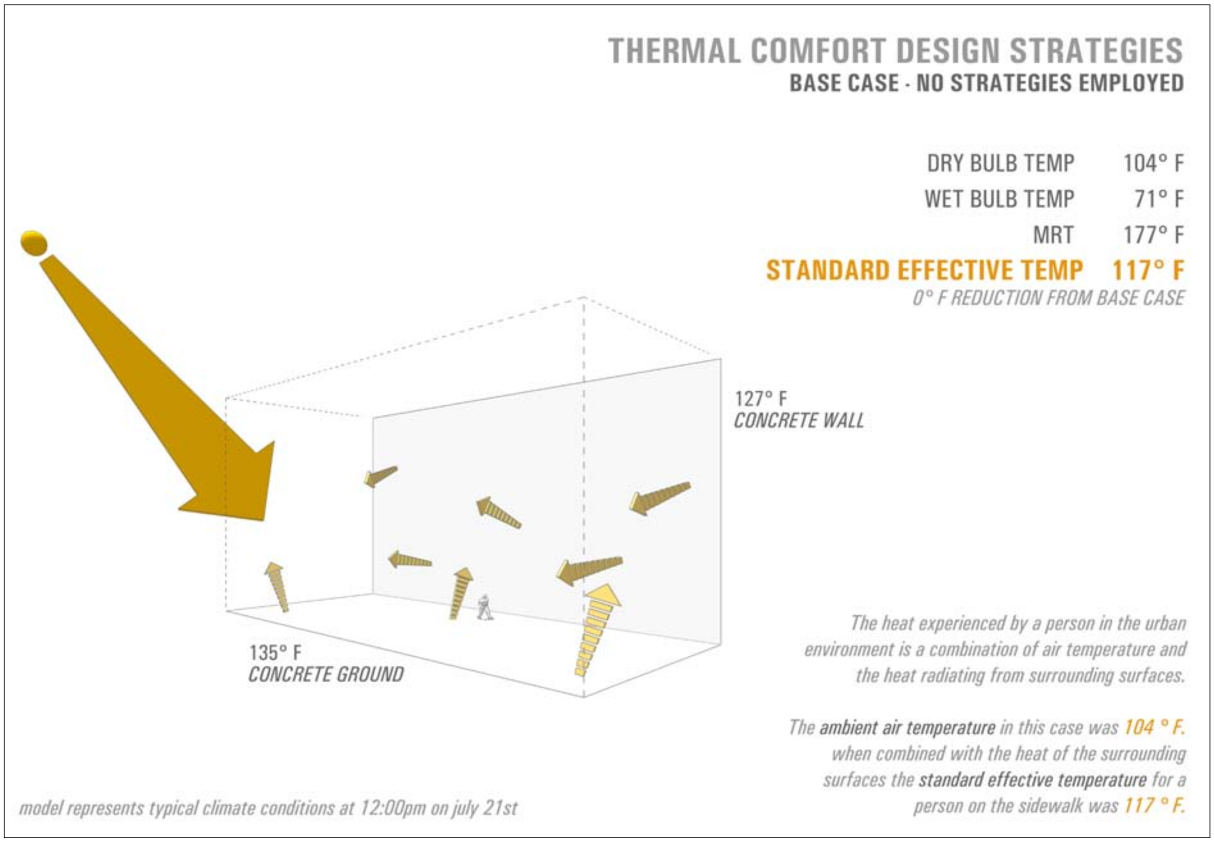


FIGURE 4-15 THERMAL COMFORT DESIGN STRATEGIES– BASE CASE

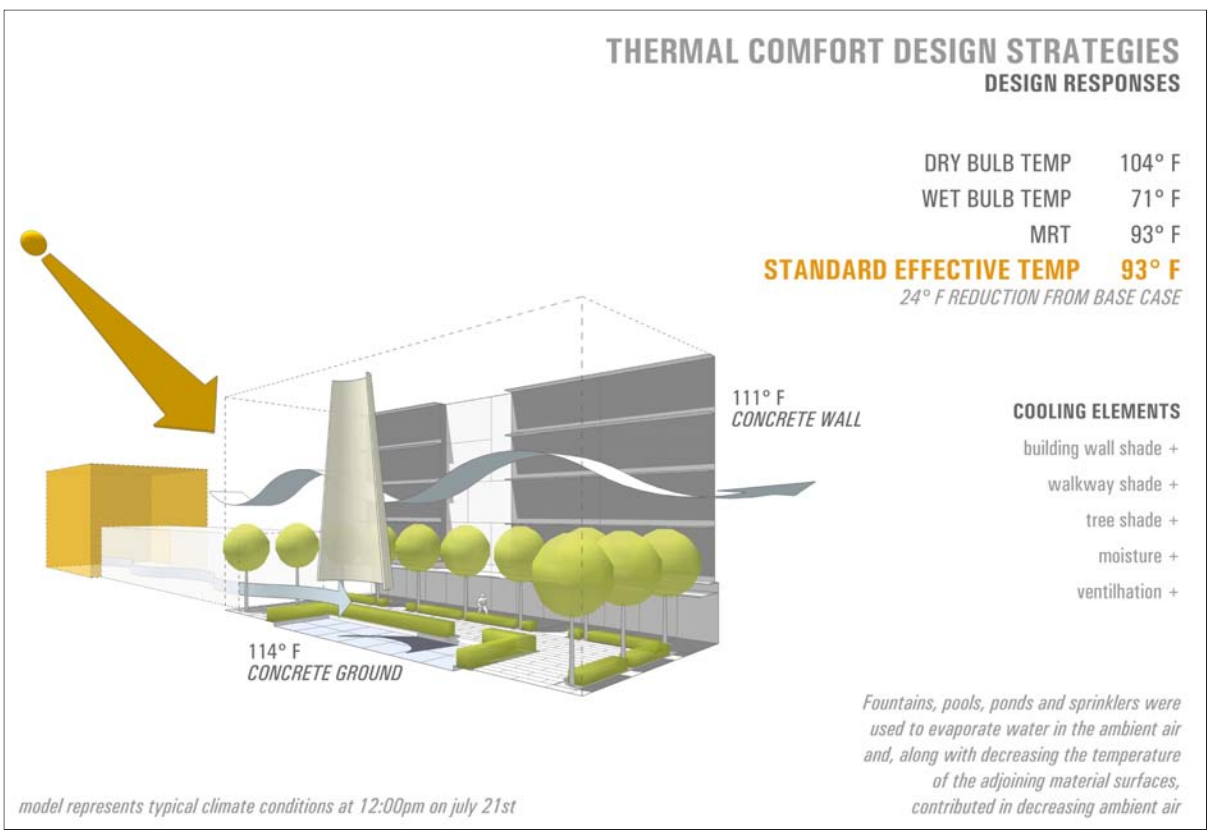


FIGURE 4-16 THERMAL COMFORT DESIGN STRATEGIES– DESIGN RESPONSES

POLICIES – BUILDING FORM AND SHADE IN THE PHOENIX CLIMATE

PROPOSED

Standards related to thermal comfort and heat gain are described below. Research is presented, and standards based on the research are then included as policies. Figures 6-5 through 6-10 illustrate the standards.

Policy 4-1 **Adopt thermal comfort and sustainability standards for building form in Downtown to optimize thermal comfort, minimize heat gain, and enhance air flow.**

Policy 4-2 **Prepare development standards for ground-level shade.**

Policy 4-3 **Encourage 50 percent of the south facing building wall adjacent to streets, sidewalks, and public spaces to be shaded at solar noon on the summer solstice.**

Policy 4-4 **Encourage the location of buildings and shade structures to maximize shade over road intersections and mid-block pedestrian crossings over major streets.**

Policy 4-5 **Construct shading materials for trellises and canopies of low mass, non conductive materials.**

Policy 4-6 **Prepare a development standard requiring 50 percent of habitable roof areas, including parking decks, to be shaded with trees, trellis vines, photovoltaic panels, or a combination thereof.**

Policy 4-7 **Prepare development standards for roofing materials to reduce heat gain using the Standard Reflectivity Index (SRI)**

Policy 4-8 **Consider establishing standards for the use of permeable paving materials for public and private develop.**

Policy 4-9 **Prepare development standards requiring construction using wall materials with high levels of reflectivity and emissivity with smooth surfaces and the ability emit heat to the surrounding environment.**

Policy 4-10 **Provide development standards that require a minimum of 50 percent shade in publicly accessible plazas, courtyards, and other public spaces (publicly or privately owned). Shade from adjacent buildings or structures can be counted towards**

the total. A minimum of 25 percent of the shaded area should be trees or trellis vines.

Policy 4-11 **Encourage a minimum 30 percent continuous live vegetative ground cover in public spaces larger than 5,000 square feet.**

Policy 4-12 **Consider including a water feature in public spaces such as courtyards or plazas. Design water features to optimize thermal comfort by wetting large surfaces and introducing moisture into the air through sprays or intermittent jets. Water features shall be located in semi-enclosed areas to contain cool air.**

Policy 4-13 **Encourage green walls to reduce excessive radiant heat accumulation in pedestrian areas receiving excessive sunlight.**