ACHEIVING COMFORT IN SUBTROPICAL CLIMATES: BUILDING A MICROCLIMATE IN THE GUANGZHOU SCIENCE MUSEUM

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Fig 1: Facade with evaporative cooling pipes and shading

WHICH ARE YOUR ARCHITECTURAL (R)SOLUTIONS TO THE SOCIAL, ENVIRONMENTAL AND ECONOMIC CHALLENGES OF TODAY?

Research summary

This paper presents a collaboration between HENN architects and climate engineering firm, Transsolar for a competition entry in Guangzhou, China. The Guangzhou Science Museum is designed to provide maximum user comfort and a memorable museum experience while minimizing impact on the environment. The museum also strives to provide comfortable spaces surrounding the building, at grade and on balconies. To mitigate the local subtropical climatic conditions of Guangzhou, China, the project extends the period of outdoor comfort levels through building a microclimate. Evaporative cooling pipes are seamlessly integrated and woven into the facade sun shade design of the building to reduce temperatures surrounding the museum. In the urban scale, sunken plazas opening to the underground level contain the cooled air with open water features, standalone shading structures, and tall vegetation. The exterior surfaces of the building lamellas are coated with a titanium dioxide layer, which contribute to purifying pollutants from the air at the micro scale. Museum visitors can further enjoy shaded, cooled balconies which perform as transition spaces between the exterior and interior environment.

Keywords: Evaporative Cooling, Microclimate, Subtropical, Adaptive Comfort

1. Introduction

Guangzhou is situated in southern China at latitude between 22 deg and 24 deg North within the equatorial belt. With a mean annual precipitation of 1694 mm and annual average temperature of 22.1 °C, a warm, humid climate dominates for most of the year.

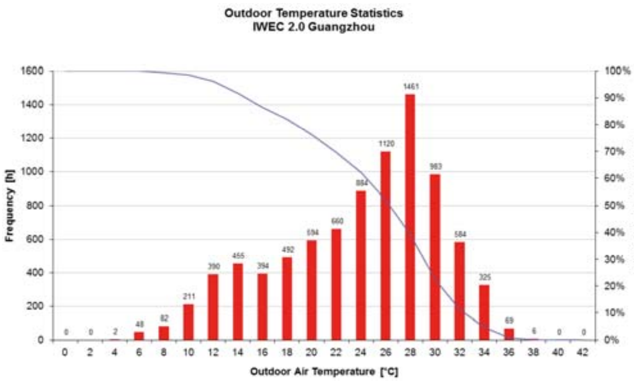

Fig 1: Guangzhou outdoor temperatures around 50% of the year are above 26°C

To assess outdoor comfort as accurately as possible in Guangzhou, human thermal comfort (the sensation of heat and cold) cannot only be defined just by air temperature, as it depends on many other ambient (solar radiation, infrared radiation, air temperature, air velocity, air humidity) and human-related parameters such as clothing and activity.

An index, Universal Thermal Climate Index (UTCI), was internationally developed over several years, then released in 2009. UTCI uses a 340-node model of the human body in order to assess heat transfer phenomena driven by many ambient paramenters which impact thermal comfort. In a climate such as Guangzhou, a UTCI in the range of 9°C – 32 °C can be rated as excellent for outdoor comfort.

UTCI >= 38		Very strong heat stress
32 <= UTCI < 38		Strong heat stress
26 <= UTCI < 32		Moderate heat stress
9 <= UTCI < 26		No thermal stress
0<=UTCI<9		Slight cold stress
UTCI<0		Moderate cold stress

Fig 2: Universal Thermal Climate Index

2. Research objectives

The Guangzhou Science Museum aims to achieve maximum comfort in its surrounding and its interior experience. From a base case scenario in Guangzhou, with a 61% outdoor comfort level (Fig 3), the first objective is to extend this percentage of outdoor comfort through multiple design strategies. Four scenarios of outdoor comfort- a) no shade, b) fixed shade, c) fixed shade and adiabatic cooling, d) fixed shade, adiabatic cooling, and increased wind, are simulated for the entire year from 9am to 9pm.

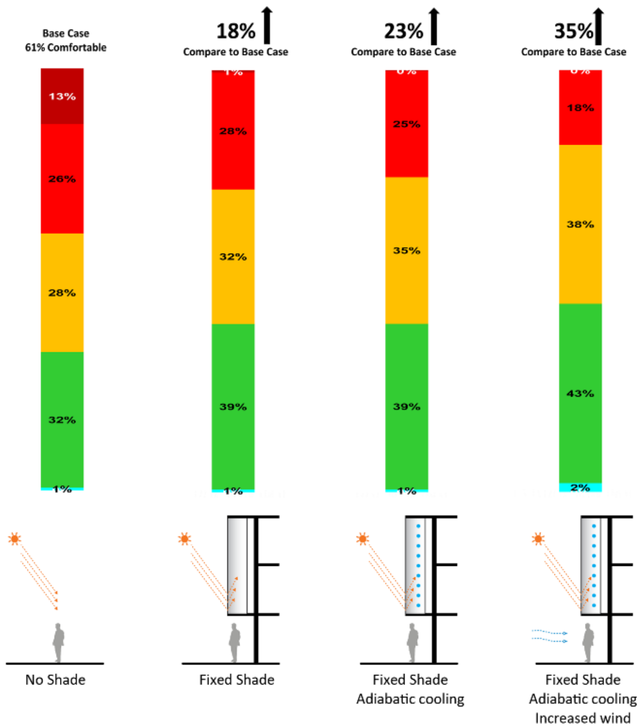

Fig 3: Four scenarios showing increasing percentages of outdoor comfort in comparison to the base case

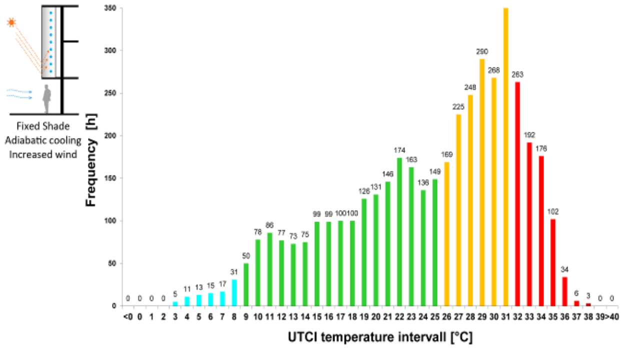

Fig 4: Final scenario with fixed shading, adiabatic cooling, and increased wind speeds achieves 35% increase in comfort levels compared to the base case

3. Approach

3.1 Façade Design

The building envelope consists of vertical lamellas and evaporative cooling pipes.

Type 1: Facade type 1 consists of aluminium fins (shading elements) in front of the glass façade. The subconstruction (aluminium profiles) of the fin is cladded with aluminium sheets. The fins are directly connected with the post and beam façade. As in Figure 4, the cooling pipes in addition to the fixed lamellas can reach up to 35% of increased comfort. Temperatures are expected to drop up to 2°C through evaporative cooling. (Fig 7) Some of the cooling pipes are also used for reinforcing the structure of the façade and for connecting the fins together.

Type 2: Facade type 2 consists of aluminium fins in front of the balcony/metal cladded façade. The fins are in some parts directly fixed at the balcony. The cooling pipes are also used as a railing for the balcony. Facade lamellas are angled to provide solar protection yet allowing for transparency and views to the exterior. Depending on the exhibition's demands, these areas can be closed for a completely artificially lit interior condition.

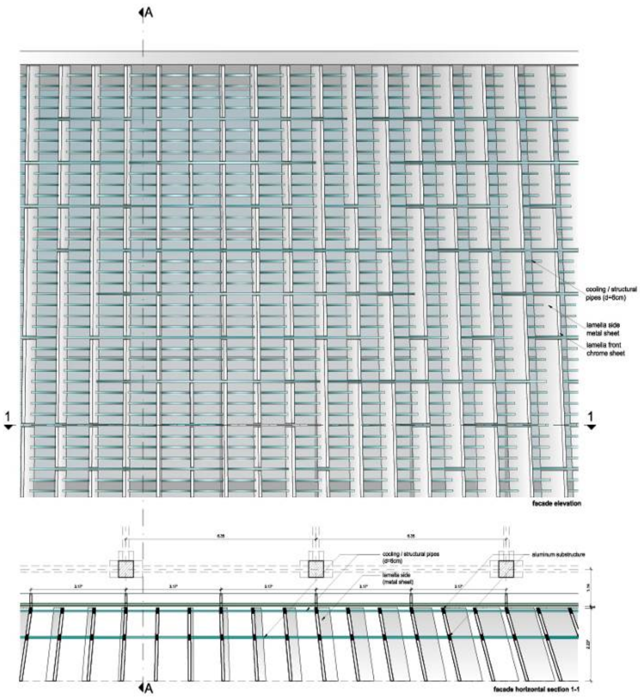

Fig 5: Elevation and plan drawings of Façade type 1 show cooling pipes woven between the vertial lamellas providing additional structural support

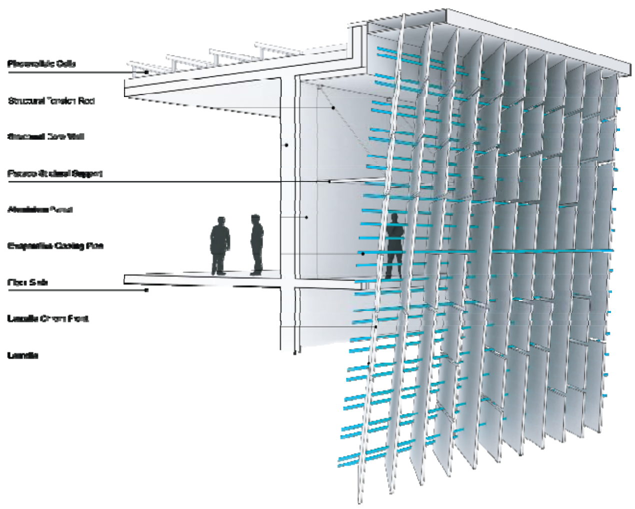

Fig 6: Section perspective of Façade type 2 with balcony transitional space behind fixed shading and evaporative cooling pipes

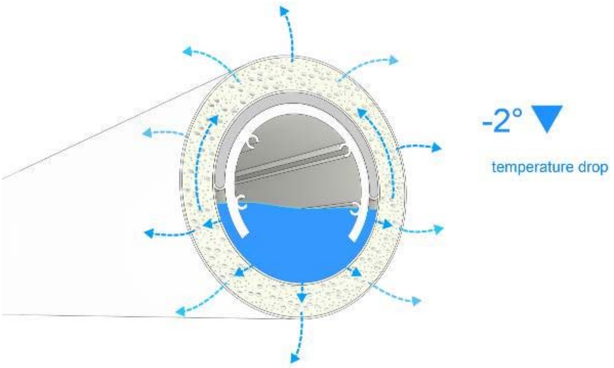

Fig 7: Porous cooling pipe section

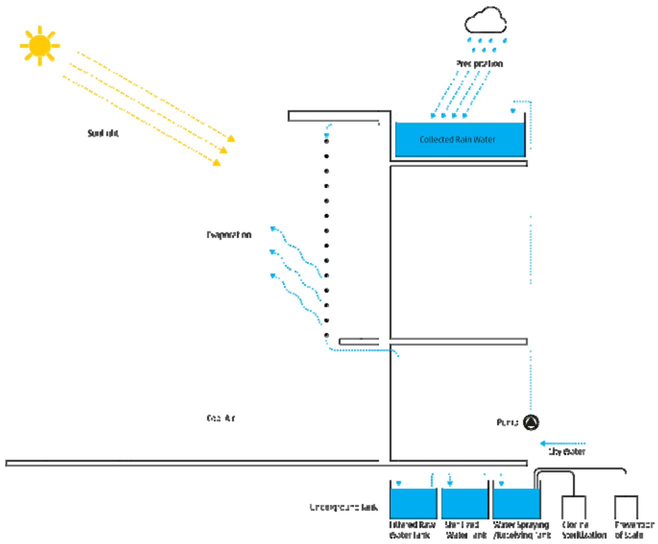

Fig 8: Water cycle of the evaporative pipes begins with the collection of rainwater

3.2 Microclimate

The microclimate surrounding the building consists of urban design strategies operating at a variety of different scales. Sunken plazas which open to the B1 levels "contain" the cooled air on site. In addition, tall vegetation and independent shading structures are important features for the microclimate. (Fig 9) The exterior surfaces of the building lamellas are coated with a titanium dioxide layer, which contribute to purifying pollutants from the air at the smallest scale.

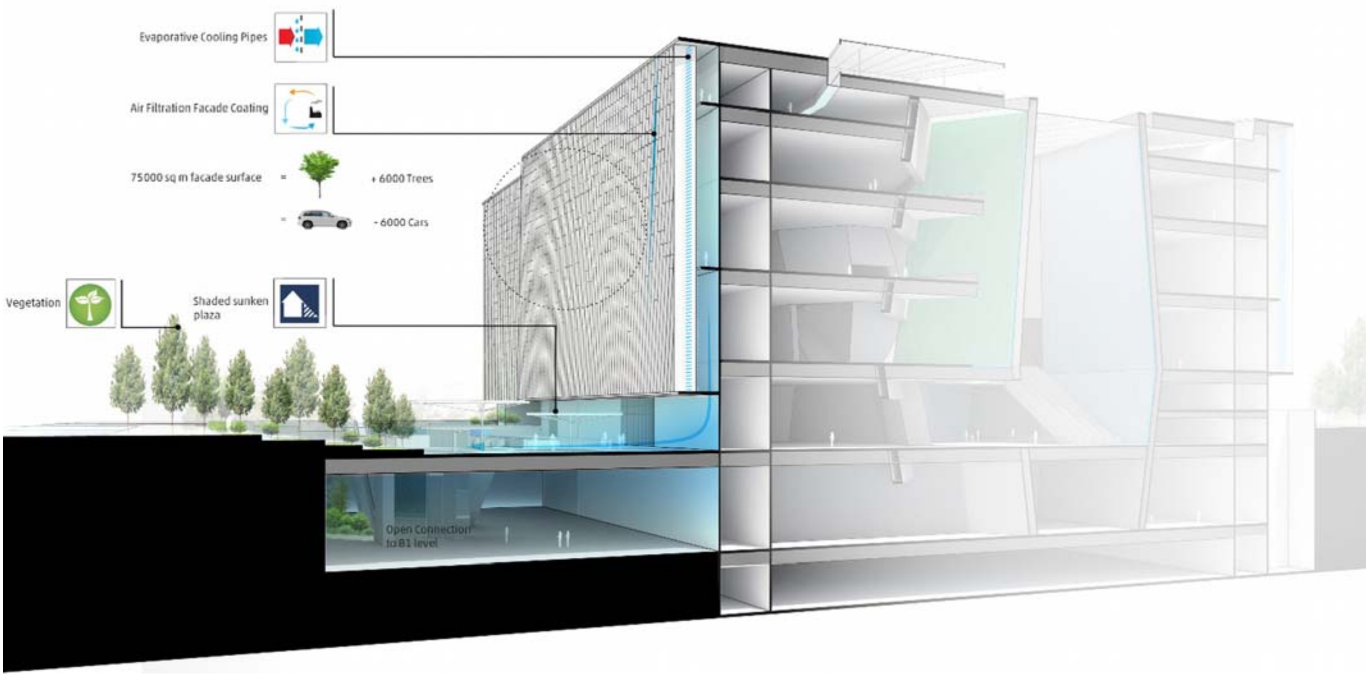

Fig 9: Design strategies within the microclimate

Fig 10: The Sony building by Japanese architects Nikken Sekkei applies cooling pipes also in the subtropical climate of Tokyo (SOURCE: Nikken Sekkei)

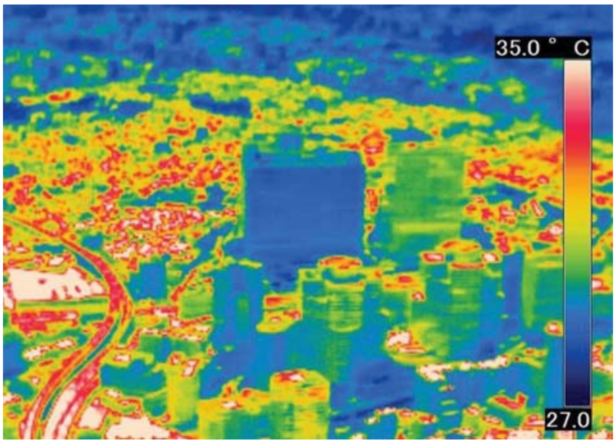

Fig 11: Aerial thermal image showing cooling effect of the ceramic east façade of the Sony building (SOURCE: Nikken Sekkei)

3.3 Interior

A well-insulated envelope is key to reducing building loads as the interior space is protected from the outdoor air temperature fluctuations. Walls with continuous insulation and high performance windows will not only reduce conduction heat gains and losses, but have minimal thermal bridging and air leakage, ensuring a long-lasting envelope. The interior of the museum applies both passive and technical active systems to control the temperature and humidity levels. The main heating and cooling sources will be the earth; otherwise known as a geothermal energy system. However, because of Guangzhou's cooling-dominated climate, a low-energy heat rejection strategy is required to prevent the earth from overheating on an annual basis. Excess heat from the central, high-efficiency heat pump and from the geothermal loop will be removed via a water loop and through a "Luna collector"; a photovoltaic-thermal (PVT) system, which generates electricity during the day and rejects heat to the cool night sky.

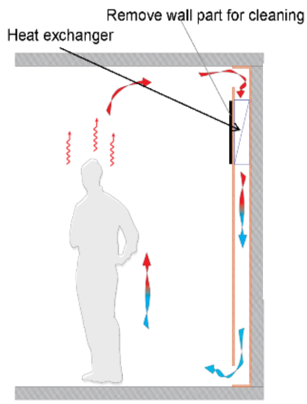

Fig 12 Gravitation driven wall system is applied to interior surfaces as a sensible and latent cooling device

Fig 13: Gravity wall system applied to the Concert House in Copenhagen by Atelier Jean Nouvel is impeccably integrated with the finishing material

Fig 14: Interior green wall atrium space in the Guangzhou Science Museum

Large interior green wall and chilled water wall surfaces act as a desiccant, dehumidifying the museum air and cooling the atrium. These large green and water walls also bring an environmental awareness to the visitors of the museum.

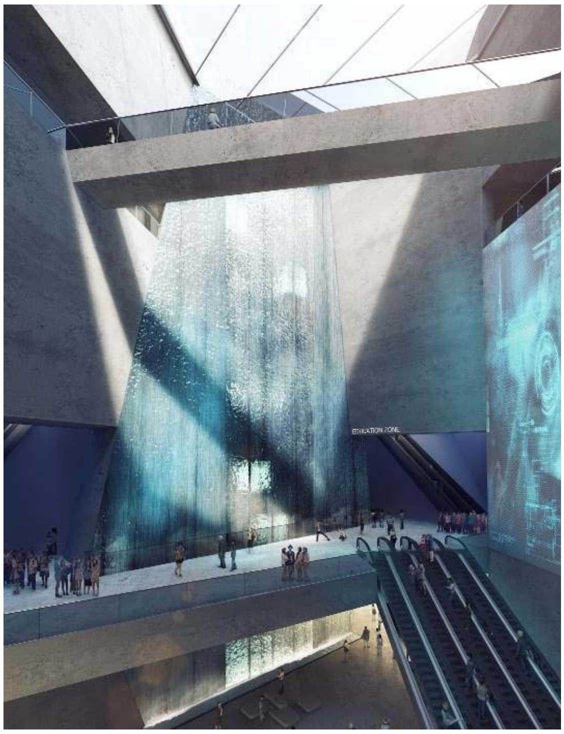

Fig 15: Interior chilled water wall atrium space in the entrance hall of the Guangzhou Science Museum dehumidifies the air locally

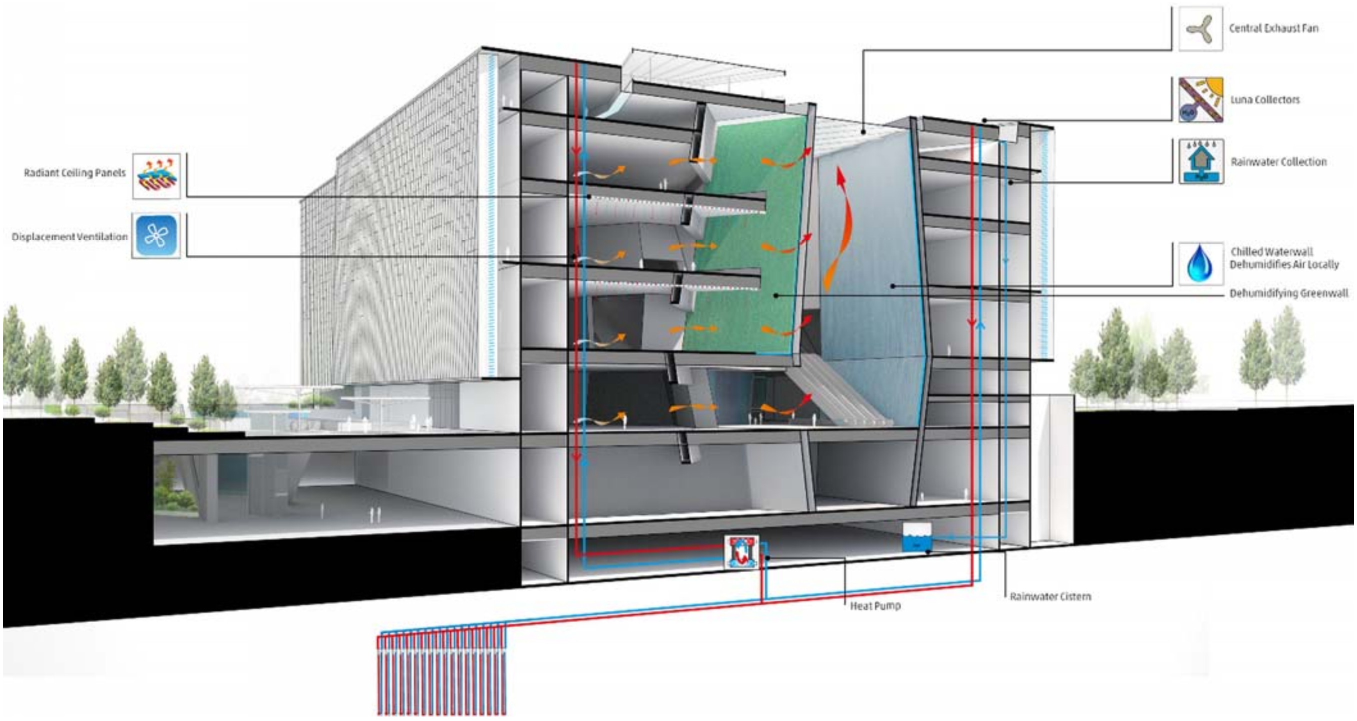

Fig 16: Hybrid passive and active systems control the interior

4. Results and Future implementation

Fig 17: Rendering of the Guangzhou Science Museum

The Guangzhou Science Museum is designed to provide maximum outdoor comfort and a memorable museum experience while minimizing impact on the environment. Evaporative cooling pipes integrated with the vertical shading lamellas are essential design elements of the building envelope. Further geometric exploration and possibilities with evaporative cooling pipes systems can extend the role of adiabatic cooling in architectural design.

5. Conclusions

Regarding the local subtropical climatic conditions of Guangzhou, China, the project increases the period of outdoor comfort levels up to 35% through the application of fixed shading, adiabatic cooling, and increased wind speeds. Temperatures are expected to drop up to 2°C through the evaporative cooling system in the facade. In its microclimate, sunken plazas opening to the underground level contain the cooled air with open water features, standalone shading structures, and tall vegetation. The interior of the museum applies both passive and technical active systems to control the temperature and humidity levels. Gravitation driven wall system is applied to the interior surfaces as a sensible and latent cooling device.

6. Acknowledgments

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