Case study

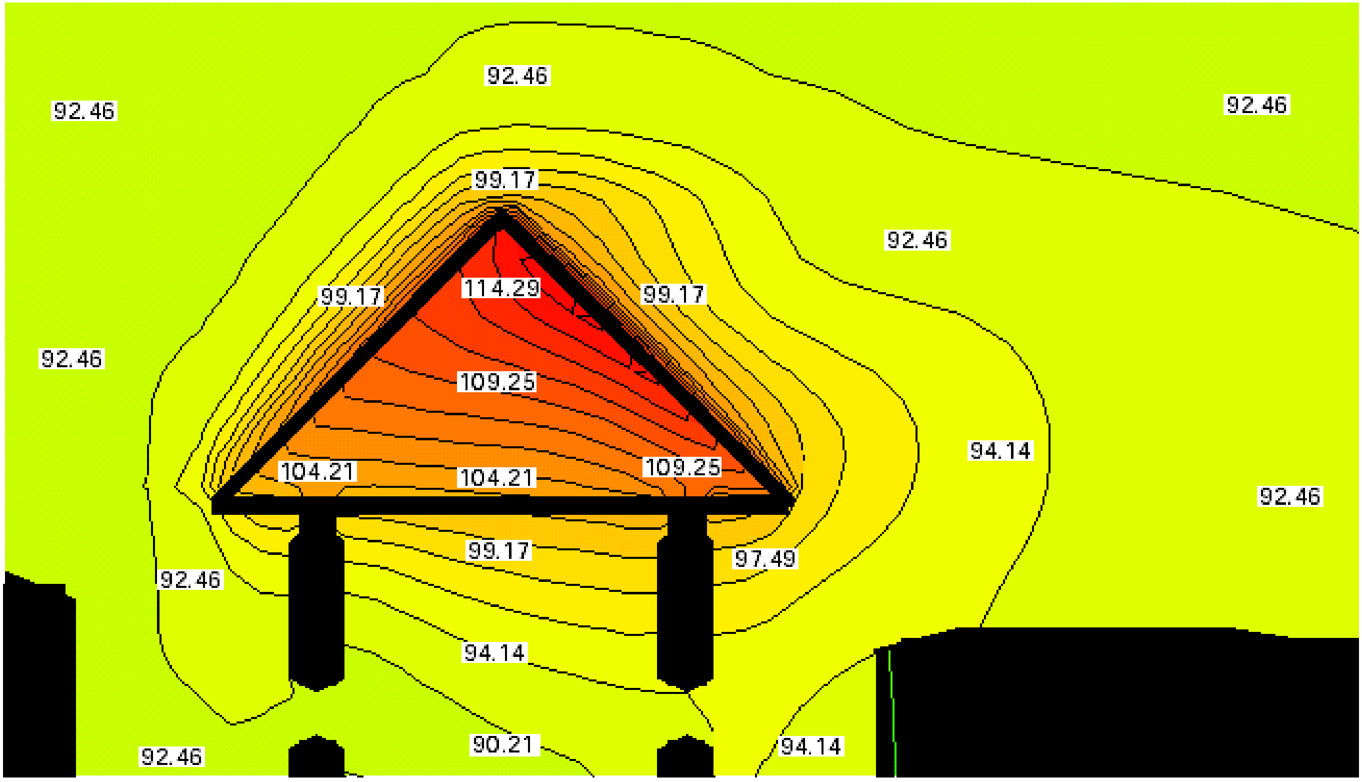
Africus improves thermal comfort in a 100-year-old naturally ventilated temple in Bangkok

Cradle's scSTREAM helps analyse the naturally ventilated temple's heat transfer and airflow performance

Africus Company Limited is a professional consulting firm working to develop design guidelines for buildings that need high performance in energy efficiency, indoor air quality, well-being, and sustainability.

The team performs simulations of heat gain, energy consumption, indoor air quality, thermal comfort, lighting, and ventilation to achieve this. They also provide assessments of building design and help building project teams achieve green building certifications such as LEED, DGNB, WELL, etc.

Africus used scSTREAM CFD solution to perform simulations for a 100-year-old temple in Bangkok. Based on this, they suggested remediation of the existing structure for better airflow and thermal comfort.



Challenges: Single program with diverse capabilities

Bangkok is home to magnificent temples, some built over 300 years ago. The city has also been tagged as the world's hottest by average annual temperature, as per the World Meteorological Organization.

To maintain optimal thermal comfort in many of these naturally-ventilated structures, given the climatic conditions, building design becomes key. In this case, it was a 100-year-old unconditioned temple located in Bangkok city. The Africus team combined Computational Fluid Dynamics (CFD) with the DOE-2 thermal simulation program to analyse the building's heat transfer and airflow performance.

The team's biggest challenge was that they needed a single, easy-to-use computer program bundled with several capabilities such as energy, lighting, daylight, comfort, and airflow simulations. If they could build a 3D model of a building and use the model to perform all the analysis tasks, it would be very useful and time-saving. They wouldn't have to recreate a newer 3D model or export/import it across several programs. They used the Design-Builder program but found it could only handle simple CFD airflow models with limited capability.

Solution: Large-scale, high-speed calculations with scSTREAM

While CFD emerged mainly to improve driving performance based on race car airflow simulations, it has assumed a key role in structural design over the years. Performing simulations before the construction stage help reduce costs while optimising thermal comfort and energy efficiency. Advanced tools such as scSTREAM can perform large-scale, high-speed simulations in the blink of an eye.

"We found scSTREAM to be optimised specifically for the design of buildings. It comes with features well-suited to airflow simulations in and around buildings in the urban environment. It can be used for both academic research and professional consulting works."

To improve comfort conditions inside Thai Buddhist temples, two case-study temples (old and new temples) were selected for survey and measurement. However, simulations were performed only on the old temple. Detailed measurement results of indoor temperature, relative humidity, and surface temperatures were reported.

In addition to the measurement results, a steady-state CFD simulation was coupled with the DOE-2 program. The result indicated that, on a typical summer day, both indoor and outdoor conditions were beyond the limit of thermal comfort, generally established at about 21-27°C (69.8-80.6°F). It was also found from measurements that indoor temperatures were higher than outdoor, especially on cloudy days during the night. These results indicated that high-mass walls played a significant role in keeping the indoor cooler than the outdoor during the day but warmer during the night. For this reason, the Africus team found that a 24-hour transient CFD simulation would provide more detailed results than a steady-state calculation. The team opted to use scSTREAM CFD solution to perform advanced, large-scale simulations.

Old temple

New temple

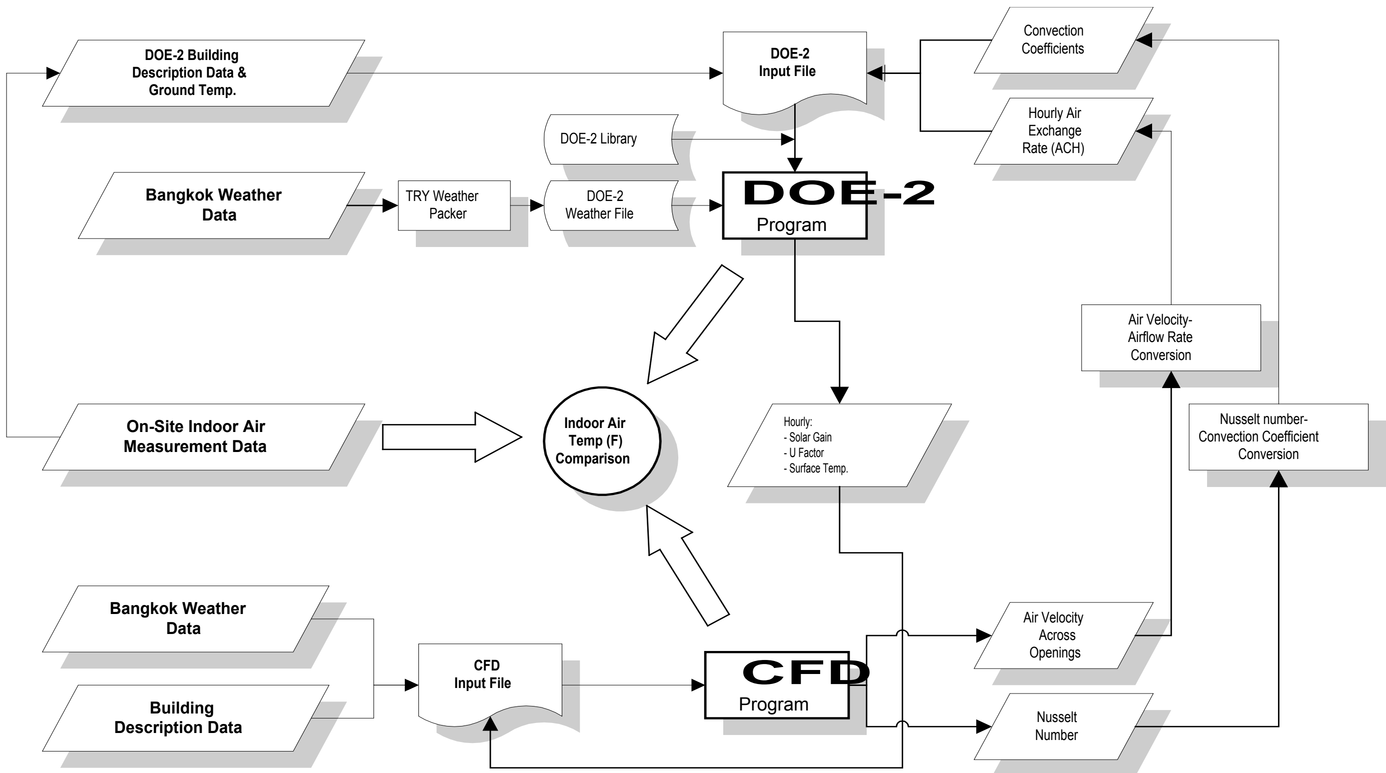
Indoor temperatures simulated by scSTREAM and DOE-2 were validated with measured temperatures taken at the site. The calibrated simulation model was used to establish the building's thermal and airflow baseline model. This provided detailed information about how the building performed and reacted to the outside environment.

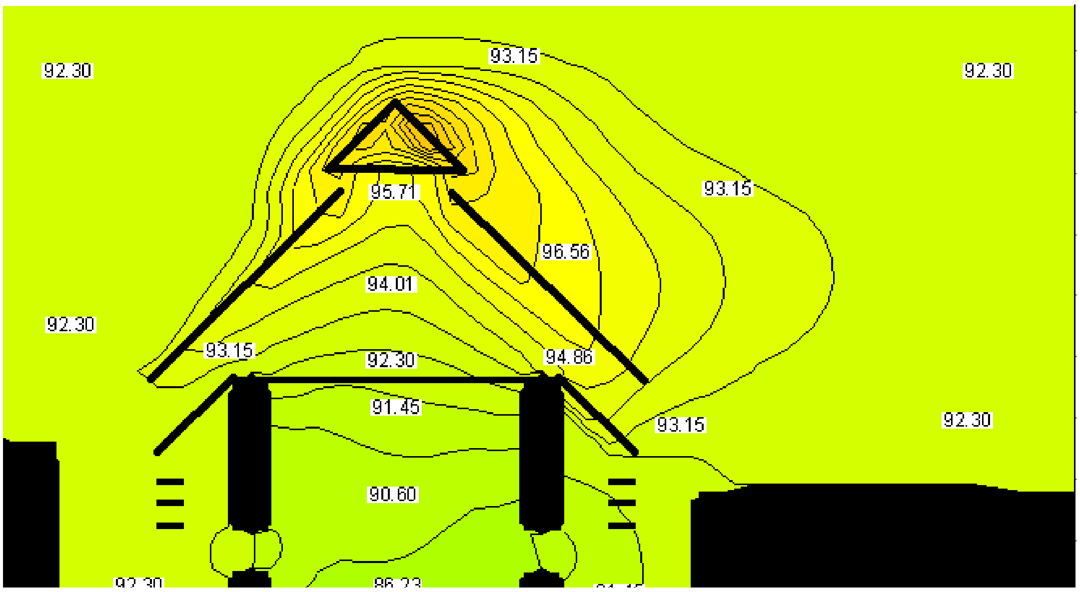
The simulation indicated poor thermal comfort conditions in the temple. The transient CFD/DOE-2 simulation suggested several remedial changes that could be implemented to improve indoor comfort. In addition, a prototype building that combined several improved design options was proposed, and the simulation of the prototype was then performed. The result indicated an improvement of the indoor thermal comfort compared with that of the current building.

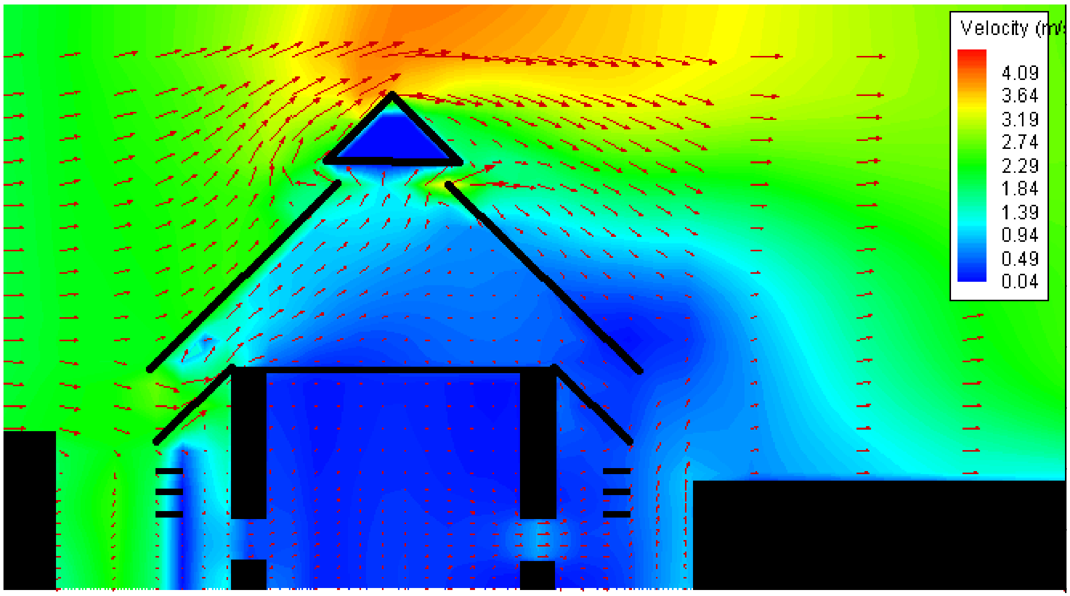
Observations and improvements suggested

Based on the accurate results of the simulations and measurements, it was suggested that the traditional Buddhist temple design could be improved with several design and operation strategies, including a low-absorptivity roof surface, ceiling insulation, solar shading, attic ventilation, and night ventilation of the temple space.

Therefore, new design options focused on two important approaches: first, how to avoid attic heat gain, and second, how to remove indoor heat more effectively.







Site observations and Bangkok weather data revealed that the outdoor air moved across the temple at a 45° angle to the front entrance, passing through the front exterior colonnades, through the interior space, and exiting through the rear of the temple. It was found from the CFD velocity plot that the airspeeds increased significantly on the outside corners and at the side openings, producing a slightly more comfortable condition.

However, inside the temple space where the major indoor religious activities occur, the CFD showed the air velocities decrease significantly, in agreement with the on-site observation of the indoor conditions being stuffy and less comfortable. It was also observed on-site that smoke produced by candles and incense was trapped inside the space, further deteriorating indoor air quality. The results obtained from the CFD simulation showed a need to redesign the proper sizes and locations of vents that would produce more airflow across the building in the evening.

The DOE-2/CFD simulation results for two weeks in summer indicate that the prototype temple performs much better in terms of indoor thermal conditions. Compared with the existing temple, it shows that the afternoon peak temperatures can be reduced by as much as 4.5 °C in the summer. The average indoor temperatures are even lower than the lowest indoor temperatures of the existing temple. In addition, the prototype building has fewer indoor temperature fluctuations during the day.

Benefits: Enhanced indoor comfort through accurate simulations

With an in-depth DOE-2 and CFD analysis, an accurate assessment of naturally ventilated buildings in a hot-humid climate was accomplished. Detailed investigations of the space planning, building material, configuration of the openings, and operational schedules are essential for developing and testing practical passive cooling techniques for unconditioned buildings in the tropics. This combination of advanced simulation tools such as MSC's scSTREAM can help designers redesign and renovate existing buildings to improve indoor comfort conditions without using a mechanical A/C system.

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Our technologies are shaping production and people-related ecosystems to become increasingly connected and autonomous – ensuring a scalable, sustainable future.

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