P5 Reflection

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This project focuses on how a retrofit facade-integrated cooling system may be implemented on an existing high-rise residential building in the tropics and how feasible it actually is. It narrows down towards an environmentally-friendly cooling method, under the premise that typical air conditioner refrigerants are gradually getting phased out under the Montreal Protocol. It is therefore an exploration into future cooling systems for existing buildings.

From Research to Design

For P2, work mostly consisted of literature reviews of cooling technologies and the context. Case studies were also investigated to gain a sense of how HVAC systems can be integrated into the façade. This helped to narrow the project down to a scope that focuses on retrofit facades meant to be attached onto existing facades, as opposed to tearing down the existing walls and completely replacing them with new ones. The case studies also shed some light on how the cooling system may be incorporated not just as something attached to the outer wall, but also forming the basis of the façade, resulting in an architectural integration of a cooling system.

For P3, the project was ultimately narrowed down to investigate 2 main ways that the system can be structured: decentralised versus centralised. While it is not so much of a surprise that the centralised concept is more cost-effective in the end, it is worth noting that this outcome could not have been based on simple assumptions of typical costs of centralised and decentralised systems, because the range of case studies included built projects of both centralised and decentralised systems, suggesting that the choice between centralised and decentralised is not clear cut and therefore calculations had to be made. Their workability highly depends on the design of the existing building and its context. It is also based on further calculations that the project was forced to alter these initial concepts to suit the context. This led to the necessary alteration of the concepts to allow for the placing of the ETCs on both the facade and roof for both concepts. The calculations were all done in Excel using equations retrieved from scientific papers. These equations were tested using values from research papers to verify its accuracy. Simple simulations were also done in Grasshopper for solar irradiation on the roof and facade, with a bit of optimisation for the facade.

Initially, the cooling load was determined merely by calculation from the statistical average energy consumption of air-conditioners in Singapore. Using this cooling load value gave some comfortable results where the solar collectors could be completely roof-based or façade-based. However, DesignBuilder gave a completely different picture, showing a much higher cooling load. This could be because the statistical average does not show the highs and lows of the data, while DesignBuilder gives the peak cooling load. Using the DesignBuilder cooling load thus ensured that the facade system could properly cater to the bedroom's cooling load in all scenarios, rather than just the statistical average, which might not even be the case in reality because it is possible that the average is attained from many extreme highs and lows. The DesignBuilder cooling capacity was thus the more accurate value to work with.

2 rounds of component sizing were done; the first was mainly to give a starting point for the sizes, while the second was to fine tune the sizes according to the equations to achieve the required cooling capacity. A few important design-related values (such as the ETC's ratio of absorber area to gross area) were determined directly by the geometry designed in Rhino used for the solar irradiation simulations. The calculations in Excel were also checked by

recalculating them using a different order of steps. Overall, this approach feedbacks if the facade cooling system works or not. With the manual component sizing, it was 'forced' to work, and it gave a feedback on how much space was needed, resulting in the conclusion in which more space was required for both facade concepts. On top of that, the focus on the worst-case scenarios throughout the project ensured a 'safety factor' so that the system was slightly oversized and working all the time.

Design development was also done to find out how much heat loss there was and to compensate for it. Excess solar heat energy collection was also investigated to know the required maintenance schedules to ensure the system worked well. Christien mentioned about how it is important to take note of the heat loss through the system. Factoring this into the calculations led to a conclusion that a small amount of ETCs had to be added to the facade in addition to those already there. The geometry of the water tank also affected both the material use and the heat loss through conduction. Maintenance costs were done by rough estimations rather than hard numbers so that a rough but fair comparison could still be done between the facade concepts. Because the entire system was eventually oversized, some calculations were also done to investigate how oversized it really is, and how much system failure can be tolerated before its performance dips below the required levels. Adding the maintenance calculations to this, it was discovered how frequent maintenance cycles had to be to ensure the system failures stay below the accepted values.

For P4, the façade module details pertaining to structural elements to attach it to the existing façade, maintenance procedures, and joint and window details were developed. Design details drew inspiration from existing window frame products designed for tropical climates, existing vacuum tube collector products, and consultations from the architecture faculty. Existing commercial products for fans and air filters were also explored to understand their dimensions and noise levels. Both Alejandro and Christien brought up valid points about the design and detailing of the façade module all the way until the P5 presentation.

Overall, the design of the facade system is informed by scientific research done beforehand. Although some assumptions were made regarding detailed engineering aspects, this project serves to give designers and engineers a rough idea as to how a tropical retrofit facade-integrated cooling system may be conceived, how it functions, under what context is it applicable, and under what conditions does it perform well and poorly. It also gives some insight into other factors that determine if such a cooling concept is feasible on a large scale. As a method of space cooling, it is relevant to areas of the world where cooling is much needed. However, the operating conditions and environments of the façade module is highly specific, so it cannot merely be replicated in any other part of the world, even within the same country. Its feasibility is therefore very limited, but as time progresses, advancements and improvements in its technology may pave way for more adaptable designs.

Relevance to Society

While it is no secret that such a retrofit façade system is far from becoming a reality, its existence directly influences the world of architecture and the built environment, as described in Section 6.2.1. The façade module in this thesis focuses on its workability. This puts the architectural form of the façade on a lower priority, which, while not necessarily taken as a negative aspect, transforms the urban environment towards a more monotonous layout. However, it could also be argued that with this specific retrofit façade-integrated cooling concept, various other façade forms could also be derived. This thesis merely focuses on the workability of 1 style. Nevertheless, it is important to know that this façade can and will alter the look of a city, which has significant effects on the future of public housing designs and their desirability. Urban heat island effect is also mentioned in Section 6.2.1, where the retrofit façade is proven to have a more detrimental effect than the traditional air-conditioner. However, this might change as desiccant technology progresses with improvements in efficiency. Any in case, the UHI problem would still pose as a barrier to the realisation of this retrofit façade system.

The application of this system was focused on tropical high-rise residential buildings, but its transferability is largely limited to the building typology. Void decks are common in Singapore's public housing buildings, but the same cannot be said for residential buildings in other countries. The massing, urban context and building orientation also largely determine the maximum effective height of the retrofit system and the effectiveness of façade solar heat collection. Large parts of Indonesia experience bad air quality due to deforestation. This limits the use of the retrofit façade system since it takes air directly from the outside. The retrofit façade system would need to be redesigned to specifically cater to such polluted regions where the air filter needs to be much more easily accessible for frequent washing.