Studio 405 – Wilkinson Building

DESC9200 Introduction to Architectural Science / Sydney School of Architecture, Design and Planning, The University of Sydney

Assessment-2: Proposal report

1. Floor / User analysis

Studio 405 is located on the southern part of level 4 of the Wilkinson building (Faculty of Architecture, Design and Planning of the University of Sydney).

This six-level building is constructed of a reinforced concrete frame and level 4 with 1866 m^2 is about 15.5% of the total building floor area. This level consists of Studio 405 and several other offices and facilities.

The main entrance of Studio 405 is in lobby 400 which is accessible from either staircase 400A or the elevator. The total volume of the Studio is 2025 m^3 (H=3.6m from floor to floor) and its usable volume is 1599m^3 (H=2.8m from floor to the false ceiling).

The net usable area of Studio 405 is about 569m^2. The studio is connected to fire exit stairs 430 & 440 from the west and south sides. The studio has a high angle view (H~19m) to Maze Crescent Roade from the southern and eastern windows and limited view to City Road from the southwestern windows. The shape of the Studio is similar to an irregular pentagon with three right angles. A smaller scaled, identical polygon structure (windows area = 62 m^2) is located at the center of the studio. Skylight Dome for capturing daylight energy for the surrounding zones is located directly above the central structure. Glass windows constitute the majority of the south-eastern to north walls (100 m^2) but 30% of these windows are internally shaded by the false ceiling. 17 awning windows conduct the prevalent south eastern and northern winds into the building. The south-western part of the Studio is connected to the outside courtyard through several windows (12.5m^2) including three awning windows which are the only openings toward prevalent western winds. A narrow window (8.5m^2) is placed on the studio's southern wall and awning windows on this wall are not usable (locked). All windows are made of aluminum frames and glazed with 6mm tinted glass. The window to wall ratio for tall walls with windows is 0.34.

The studio's floor is covered with a dark carpet and the main area has been partitioned into several adjustable zones. Each partition consists of two or three blocks (1.7*0.6*2m). These blocks are wooden shelves and their back sides are covered with PET (Polyethylene terephthalate) felt panels with 1cm thickness. Students can place their belongings in the shelves and pin sheets on the PET panels. These panels can also absorb sound energy. In addition, the southern walls are all covered with the same material. The false ceiling acoustic panels are made of compressed straws. Fluorescent lights and other facilities such as fire sensors, wifi boosters and air conditioning vents have been installed on the false ceiling and other related electro-mechanical systems and ducts have been installed behind the false ceiling. The artificial illumination of the studio is provided with a total number of 260 (252 *38 W + 8 * 20W) florescent lamps. Studio 405 is used for a variety of functions. The division of the space into factions makes it suitable for use as classrooms where lessons, presentations, seminars and workshops are carried out. Currently, 100 white portable study tables are in use in the studio which provide a total of 162m^2 of desktop space for up to 150 users.

The flexible arrangement of furniture allows for groups to use this space for meetings and discussions. There is no computer room in this studio and students use their own devices. There are 9 portable large screen monitors and a sun emulator for educational purposes.

2. Floor Measurements

Heat:

The internal temperature of Studio 405 has been measured in 8 locations for two different times of the day (AC ON) and night (AC OFF) as has shown in table 1. A, homogenized temperature distribution (Orange graph) with an average of 23.3 C has been registered for night (10 pm) while air conditioning was Off and the outdoor ambient measured 17.6 C. The comfortable internal temperature of the building can be a result of the building's heat mass [6]. The average daytime internal temperature was measured to be 24.3 C with AC ON which is 2 degrees warmer than outdoor ambience. A total of 48 ceiling ventilation vents (total area = 6.7 m^2) conduct the AC air flow in the studio. The average air flow velocity measured for six vents is 0.8 m/s. Natural ventilation has been limited to 17 opening windows on the eastern side and 3 opening windows on the western side. Most of these widows are kept closed to prevent the nuisance of high-level air flow. The main functions of these windows are providing sunlight energy for natural illumination and warming up the studio [3].

Light:

Daylight illumination is provided through 183m^2 glazing area. Natural illumination for the horizontal plane (over the tables) has been measured to be between 100 lx to 1000 lx close to windows. Furthermore, measurements have shown that the current coated windows can reduce sunlight illuminance by 50 percent. The majority of the studio's artificial horizontal illumination is provided by 260 (252 *38 W + 8 * 20W) florescent lamps attached on the ceiling. Table 2 shows a combined (natural + artificial) average illumination of 597 lx against an average artificial only illumination of 424 lx for 15 points in Studio 405. Vertical illumination has been measured to be between 50 lx to 230 lx. The lowest illuminance (56 lx) has been measured in the entrance corridor which is lit with two small fluorescent lamps.

Sound:

The floor has been measured for background noise, reverberation time, speech intelligibility (STI) and intruding noise. As there are several internal noise sources inside the studio, the background noise (Yellow curve, Table 3) has been measured at a relatively quiet time when only 5 people were in the studio. This method measures the room criterion according to standard AS2107 which has been suggested for noisy offices and has shown that the studio's background noise is compatible with RC45 for frequencies between 250 to 1k (important for speech). The Red curve has been measured while the noisy fluorescents were on and shows more than 10dB roar noise on 250 Hz. The source of this noise can be the vibration and resonance of iron core ballasts. The purple curve has been measured close to zone S4 where a high-level noise comes from the ceiling (maybe HVAC noise). This curve is much higher than the max RC 50 standard curve and can result from mechanical vibrations. For measuring the reverberation time and speech intelligibility, the studio's impulse response has been measured for 6 different points and the accurate value of RT and STI (speech transition index) has been calculated with aarae (acoustic software developed by Densil Cabrera). Table 4 shows the average RT and the calculated average speech intelligibility for male and female speakers (at 3m distance) is about 0.8 which is acceptable [1].

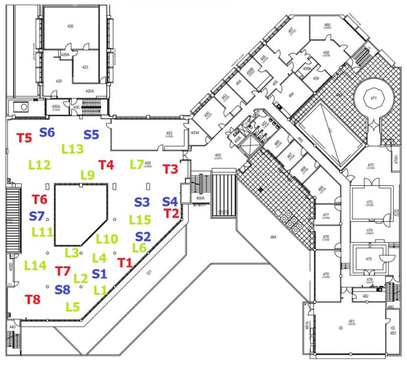


Figure 2. level 4 of Wilkinson Building building floor plan and Studio 405measurement spots (T- temperature, L-light, S-sound)

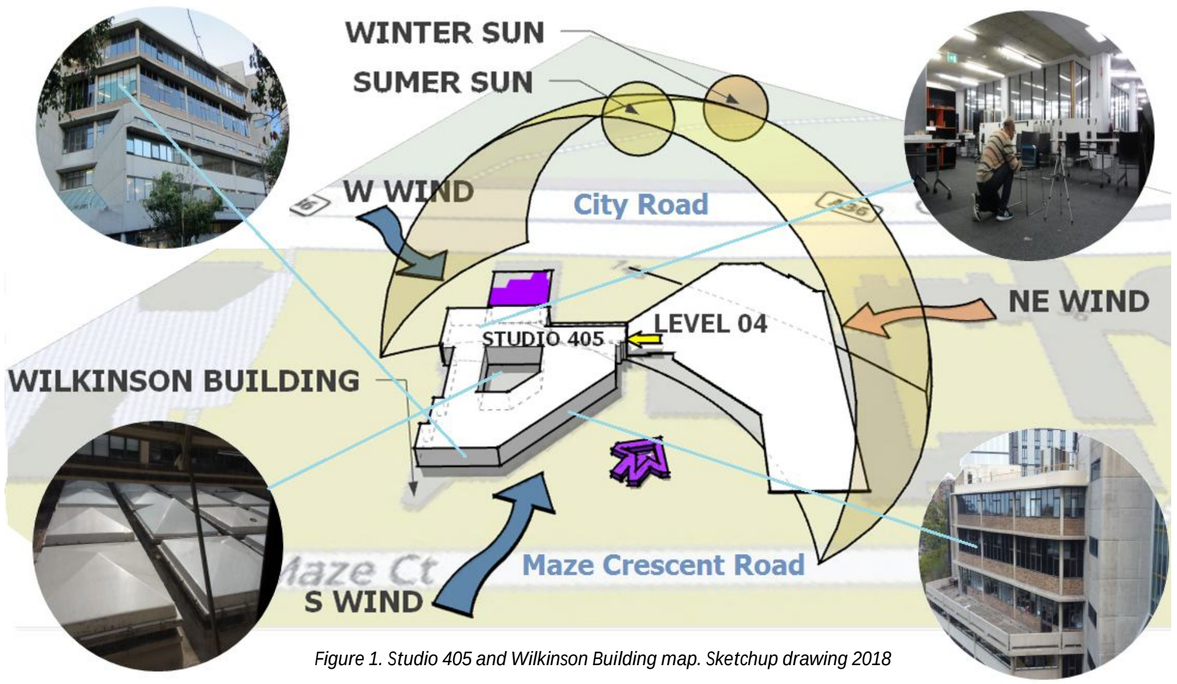


Figure 1. Studio 405 and Wilkinson Building map. Sketchup drawing 2018

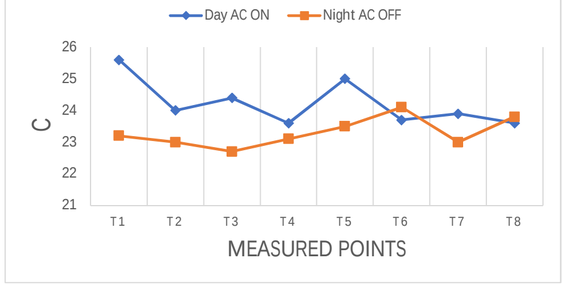


Table 1. Temperature measurements graph

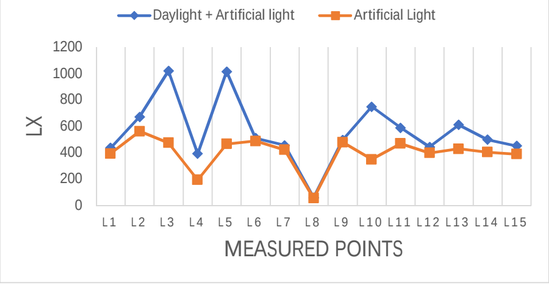


Table 2. illumination measurements graph

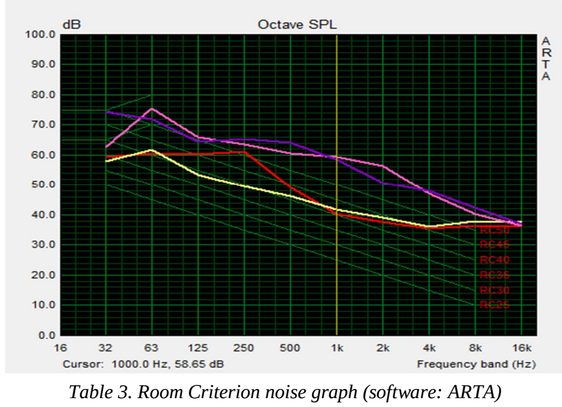


Table 3. Room Criterion noise graph (software: ARTA)

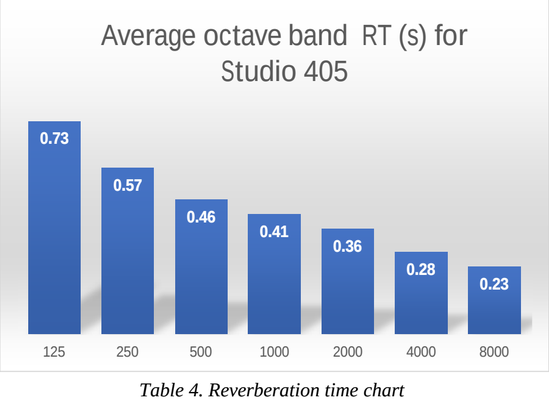


Table 4. Reverberation time chart

3. Heat, Light and Sound related issues

Heat:

- As 72% of eastern walls are glazed with a single layer of 6mm glass, a great amount of heat loss in winter and heat gain in summer can occur which results in unnecessary energy loss.
- The glazed area of the north facing side of the building is much lower than that of the east facing. The central daylight catcher structure can pump more heat in the studio in the summer as it conducts the heat energy of encapsulated warm air beneath the skylight domes through a single layer glass [4].
- Due to a low ceiling and unbalanced opening windows between two sides (33m distance) of the studio, natural cross ventilation cannot occur properly.
- Heat loss occurs due to the high ratio of wall surface to volume.

Light:

- Natural illumination is not enough for the studio's purposes due to tinted windows and shaded skylight domes by the level 5 building.
- The suspended ceiling's color and texture is not suitable for diffusing the horizontal light.
- Glare is produced due to contrast (the false ceiling is a light absorber) and direct and reflected glare are caused due to the position of lamps without diffusers [7].
- Many of the florescent lamps flicker.
- The iron core ballast of fluorescents produces noise and heat.
- Manual lighting control.
- Ununiform natural illuminance distribution.
- Daylight and artificial lights have been blocked partially with partitions.

Sound:

- The intruding outdoor road noise, especially at low frequencies, is dominant.
- The nuisance of florescent (roar) noise in the south-western corner.
- Great amount of hiss according to measured room criterion RC noise rating (table 3).
- Noise and vibration at the northern part due to the ventilation system.
- The amount of reverberation time for low frequencies is much higher in comparison to high frequencies as the surface area of high frequency absorbers (carpet, ceiling tiles and PET felts) is much higher in comparison to low frequency absorbers (glass panes and cavities). This problem can reduce speech clarity.

Integrated Retrofit strategies proposal:

To provide the optimum comfort level in heat, sound and light in studio 405, the following have been proposed as feasible targeted retrofit solutions.

1. Replacing the current glazing for south, west and east with double pane (2*6mm) low emissivity (low E) glass but for achieving the max solar gain in winters, the northern glazing must be clear. For enhancing insulation between the internal space of the studio and central skylight, especially for reducing the heat conduction in summer, the central glazing should be changed to clear double pane glass [4]. The double-glazed window should also be able to reduce outside noise. To achieve optimum transmission loss (40dB at 1kHz), the gap space should be at least 25mm [1]. This amount of reduction can reduce the outside (City Road) noise level and adjust it to around RC40 which, according to AS2107, is acceptable for a multipurpose educational studio. The onsite light measurements have shown that the natural low E glass is able to reduce sunlight illuminance to halve which can be useful in controlling the summer sun glare in eastern and western windows but a fair amount of natural light can get in.

2. The acoustical and thermal quality and efficiency of the Studio's suspended ceiling can be enhanced by using tiles with multi-functional acoustic panels. Panels with high thermal resistance (about 6.70m^2. °C/W) and uniform sound absorption coefficient (about 0.75) can help to treat the unbalanced reverberation time due to a uniform octave band absorption and improve the building's thermal envelop. The finishing color and texture of the ceiling tiles also play an important role in light scattering and reducing glare [9]. For this reason, a white mat tile can improve illuminance distribution and reduce glare.

3. Through the use of appropriate acoustic materials on the suspended ceiling, it is possible to replace the carpet with tiles or slates (even wood) which can provide a good amount of surface mass to store winter daytime solar gain and summer nighttime coolth as suggested by ASHRAE (climate consultant 2018).

4. The average amount of artificial illumination in studio 405 (424 lx) is categorized for workshops with medium bench work (AS/NZS 1680.2.3:2008), while different activities in the studio need adjustable illumination between 240 lx (seminar) to about 600lx for finer bench works. For solving artificial lighting problems due to the florescent lamps, LEDs can be a suitable alternative. The light efficiency of an LED tube is about double in comparison to fluorescents and replacing the current 38W fluorescent lamps with 20W equivalent LED tubes with proper diffuser (glare reduction and illumination uniformity) and dimmer controls can provide an efficient and long lasting controllable illumination system. As LEDs do not use ballast transformers, the noise problem (hiss and roar) resulting from the current lighting system will be solved.

5. The existing HVAC system (300KW air cooled chiller and gas hot water), ducts cold or warm air to Studio 405 (week five). The chiller itself has been placed on the roof in the location of the vibration noise but the noise source is not completely clear as it is audible all day. The octave band on the spot noise source table 3 shows a peak around 500Hz which can be recognize as a high-speed rotating rotor such as a water pump or ventilation fan. Using proper sound proof materials can reduce the noise down to 40dBA or lower [1]. With implementing proper insulation strategies such as using absorbent baffles in ducts and using elastic materials for insulating the pipes, the ceiling vibration noise can be brought under control [7].

HVAC System proposal:

Considering the elevation, geometry and functionality of Studio 405, natural cross ventilation cannot be a feasible solution for providing comfortable internal temperatures and fresh air for most seasonal times. For enhancing the ventilation system's efficiency and increasing the internal spatial perception (by increasing the height of the suspended ceiling), an Active Chilled Ceiling and Beam HVAC system is proposed. This system is ideal for low floor to floor studios with higher dry bulb temperatures and uses 100% of outdoor air with acoustic advantages [6]. The proposed system works with Hot Water (HW) for warming and Cold water (CW) for cooling. Aside from the high installation cost, this system has several advantages such as high efficiency and low maintenance costs in comparison to chillers and heat pumps. According to ASHRAE Handbook [2], this system can enhance the total human thermal comfort by controlling the indoor air temperature and mean radiant temperature. The average height of commercial active beams is less than 25cm which can reduce the total ceiling space required.

HVAC load estimation:

The heat gain sources of Studio 405 (in the most extreme cases) can be estimated from the number of LED lights, appliances, users and the heat gain from eastern and skylight double pane low E windows in a hot summer day [3]. The heat gain for 150 occupants is about 26 kWh [3]. By including other factors, the total heat gain can be estimated to be about 60 kWh. By dividing this number by a nominal cooling capacity for an active chilling beam (1.8 kWh), we can estimate that about 33 beams will be needed to adjust the studio's temperature to around 25 C in a summer hot day. Usually, the beam's heating capacity is lower (1.2kWh) but as heat gain of users and other appliances is an advantage in winters, this capacity can be enough to warm up the studio to up to 22 C (Psychrometric chart Sydney).

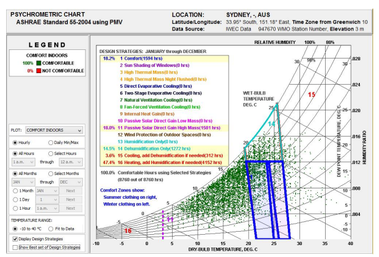


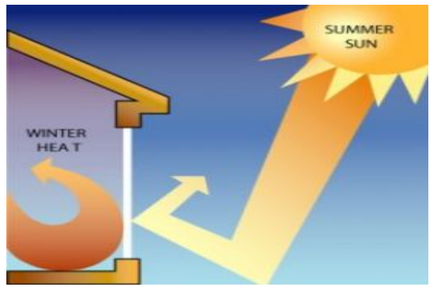
Figure 3. Sydney's Psychrometric Chart (source: climate consultant)

Energy conservation:

The estimated energy conservation resulting from the proposed retrofit solutions in comparison to the current estimated energy consumption are shown in the table below:

Energy Audit for STUDIO 405	Electricity kW/annum	Estimated price$/2017	Working hours/annum
Current HVAC [6]	76246	~22k	3024
Proposed HVAC	46080	~13.3k	3024
Florescent Lighting	62362	~18k	5376
Proposed LED Lighting	28385	~8.2k	5376

According to the above table, electricity consumption has been reduced 60.4% for HVAC and 45.5% for the illumination system. More energy can be conserved if these systems are fully controlled by digital programming systems. Using the double-glazed windows and proper insulation on the suspended ceiling will be effective methods of conserving the internal heat gain in winter by floor heat mass, reducing the extra heat gain in summer and keeping the internal coolth provided by HVAC.



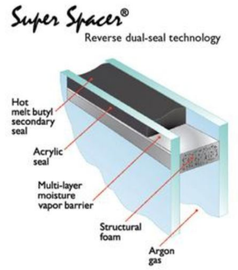


Figure 4. Low E double pane glass can reduce summer heat gain and conserve the internal heat gain in winter. It is also a good sound barrier [8]. Low E coating has been placed on the inner side of outer pane and a great portion of the outdoor heat can be absorbed by the outer pane. This combination can create very low solar gain and let enough light get in [4].

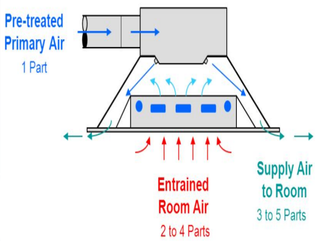


Figure 5. Active Chilled Beam (ACB) HVAC system [2]. Energy-Efficiency, improved acoustics.

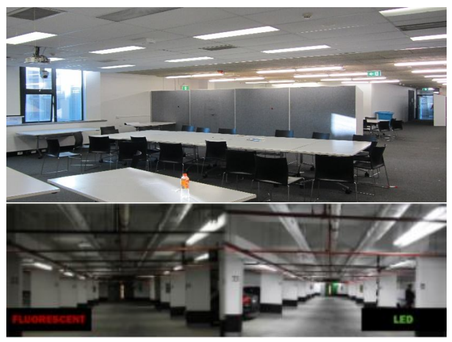


Figure 6. Two different lighting concepts in Studio 405. The glare of ceiling fluorescents on the compressed straw (darker ceiling) is much higher in comparison to the same lamps behind the diffusers on the white ceiling.

Figure 7. LED tube lighting efficiency verses Fluorescent. LED tubes can preserve their brightness for a long time [5].

Figure 8. G04 sealed Sky dome can accumulate summer warm air in the elevation of Studio 405 windows and conduct heat through the glazing. Double pane windows can reduce this problem through the high thermal insulation [4].

Figure 9. 300kW Chiller over the 5th floor roof and exactly over the spot where the high level noise has been measured in Studio 405 (Table 3, Purple graph).

References:

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[2] *Francis, W. (2014). Chilled Ceilings / Beams Working Principles & Applications [PowerPoint slides].*

[3] Heat load calculations – heat gain for air conditioner sizing. (2018). Retrieved from http://www.tombling.com/cooling/heat-load-calculations.htm

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[9] Zumtobel Lighting. (2018). The Lighting Handbook [Ebook]. Dornbirn.