Towards a Safe Sun-bathing Canopy

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ABSTRACT: In many countries with fair-skinned populations, skin cancer is major health problem. Over-exposure to UV radiation is a leading cause. Along with the use of sun-screen, environmental shade is a recognised strategy in reducing UV exposure. In temperate climates protection from UV is often required when the warmth of sun is desired for comfort. The use of opaque shading materials can form spaces that are too cool for comfort. This is especially relevant at outdoor swimming pools were people often relax by sun-bathing. Some transparent and translucent materials transmit the sun's warmth while shielding UV. Assuming diffuse UV can be controlled, a laminated glass sun-shade structure could allow people to enjoying sun-bathing safely without the risk of sun-burn.

This paper presents a case study of a recently constructed glass clad sun-shade structure at an outdoor swimming pool in Wellington, New Zealand. The preliminary shading design study is presented as well as the results of a study of UV protection and thermal comfort performance of the built structure.

Keywords: ultraviolet radiation, sun shade, skin cancer

1. INTRODUCTION

In New Zealand, skin cancer is recognized as a major health risk. In the 1980's, the Cancer Society of New Zealand (Inc) (CSNZ) ran the first public education campaign to promote UV protective behaviour [1]. The CSNZ's 2000 publication, Undercover: Guidelines for shade planning and design [2] promoted the use of environmental shade as a strategy to prevent over-exposure to UV. In response to this growing awareness, in 2003 the Wellington City Council commissioned a shade audit of a public open-air summer pool in the inner city suburb, Thorndon. As a result, two shade canopies were installed at the pool in October 2005. The paper reports on the recommendations of the shade audit and research carried out in February 2005 into the effectiveness of the as-built canopies.

Firstly, the paper discusses ultraviolet radiation and the need for protection. Secondly, the recommendations of the shade audit are explained and the subsequent shade initiatives at the pool presented. The objectives and methodology of the case study are outlined. Findings are presented and discussed then conclusions are drawn.

Figure 1: Thorndon Summer Pool

2. ULTRAVIOLET RADIATION

2.1 UV Index and overexposure

UV levels are internationally presented by a UV Index, an international standard promoted by the World Health Organization (WHO) [3]. WHO recommend that personal protection should be used when UVI is greater than 2, although the health risk is relative to skin-type as displayed on the following chart.

	UV Index								
Skin Type	1-2	3-4	5	6	7	8	9	10	11+
White- does not tan	low	med	high	very high	very high	very high	very high	very high	very high
White – tans easily	low	low	med	med	high	high	high	high	very high
Brown	low	low	low	med	med	med	med	high	High
Black	low	low	low	low	med	med	med	med	high

Figure 2: Risk in relation to skin type [4]

At UVI 2, the UVR_{eff} in standard erythemal doses (SED's) would be 1.8 SED per hour. Generally 2 SED is sufficient to cause erythema or sunburn in people with sensitive skin. Research also confirms that children are more vulnerable to UVR over-exposure and that sun-burn in childhood can lead to melanoma in later life. [5]

2.2 UV levels at the site

Wellington, at latitude 42.5 degrees south, has relatively high levels of ambient UVR. In comparison with latitudes in the northern hemisphere: maximum summer UVI in NZ can be 12, compared to around 7 in UK and levels of 9 or 10 in the Mediterranean. This is largely due to the closer Sun-Earth separation, the clear unpolluted skies, and the relatively low ozone amounts in the Southern Hemisphere summer [6]. Based on recorded data, the NIWA UV Atlas [7] provides hourly estimations of UVR levels in previous years. When the pool opens in late October, estimated UVR ranges from UV index 3 at 10am and 4pm to UV Index 7.5 at solar noon. (Solar noon is at 1pm during daylight saving time in NZ). UVR levels are highest in late December, when levels range from UV Index 6 at 10am and 5pm to UV index 12.5 at 1pm.

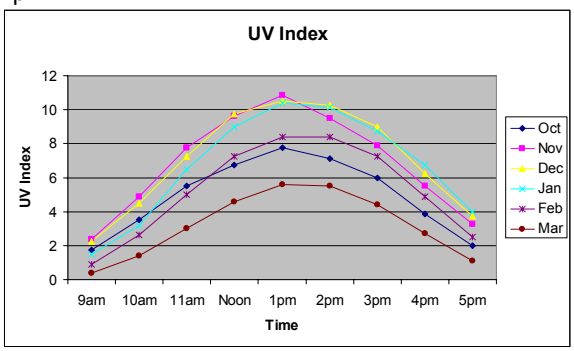

Figure 3: Average monthly UVI in Wellington, New Zealand

The UV values from NIWA UV Atlas are for an open field situation. In an open field situation, it might be expected that half the exposure would be received from direct UV and half from indirect UV reflected from the atmosphere [8]. The distribution of indirect UV is relatively even varying by a maximum ratio of 2 to 1 between of the sky closest to the sun and the sky on the horizon [9]. In an inner city site in harbour rimmed with hills, the view of the sky is restricted by neighbouring buildings and the skyline.

At an open air pool, UVR exposure could be increased from UV reflected off the surface of the water. The relatively high UV levels are more dangerous due a temperate climate, cooled by sea breezes. Often people are comfortable in the full sun, when UV levels are high. In central New Zealand, the UV Index is over UVI 2 for eight hours a day in summer, but 69% of this time the air temperature is too cool for comfort [10].

3. SHADE AUDIT RECOMMENDATIONS

A shade audit is a process promoted by CSNZ [2] which involves assessment of the existing shade provision, evaluation of shade availability and needs, and identification of solar protection opportunities by management practices and the better provision of shade.

The Shade Audit: Thorndon Summer Pool report [11] recommended: provision of information on the dangers of UV, promotion of the need for personal UV protection (sunscreen, hats, sunglasses and swimming googles), display of real time UVI levels and the provision of a large shade canopy. The shade canopy would provide protection for pool attendants, parents supervising their children while swimming, swimming instructors, spectators, and pool users sun-bathing and relaxing after swimming. The location and dimensions of the shade canopy were recommended on the basis of the analysis of seasonal and daily UV levels and the 3D Autocad modelling of sun-paths between October and March. The design proposed an 18m x 8m canopy over the existing concrete terraces at 4m high at the pool edge and 2.7m above the upper level terrace. Shade would be available over two thirds of the terraces (a popular sun-bathing site) over the middle of the day.

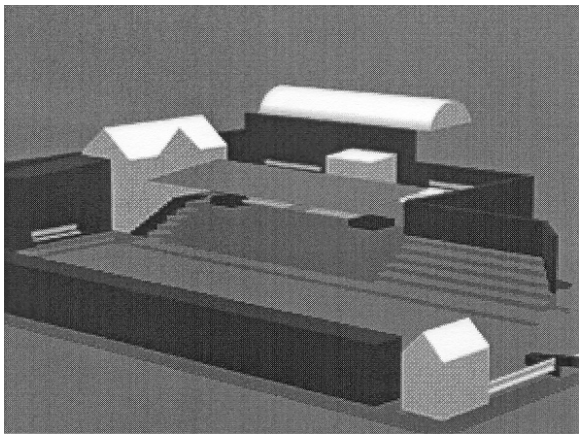

Figure 4: 3D CAD modelling of projected canopy shade - 11am 22 February. Estimated UVI 6.5.

As both pool staff and patrons had expressed concern that the shade would restrict the welcome warmth of the sun, the report recommended a shading material of specialist glass or polycarbonate sheeting which would allow the passage of heat but filter UV. A variety of shade types to give a range of comfort conditions to suit varying patron needs was also suggested and the specification of a water-proof material to give wet weather shelter for pool users and their belongings.

4. UV PROTECTION INITIATIVES

In 2004, Cancer Society of NZ (Inc) commissioned the design of a real-time UVI meter. A prototype was installed over 2004/05 summer. A display indicates real-time UVI on a scale of 1 to 12. The graphic design coordinated with the national campaign introducing the UV Index to the New Zealand public.

On the basis of the shade audit recommendations the Wellington City Council (WCC) commissioned Wellington architects Hunt Davies Tennent to upgrade the terraces and design new canopies. The canopies were completed for the seasonal opening of the pool in October 2005. The design varied from the Shade Audit recommendations in several ways.

Figure 5: Real–time UV Index meter. For more information on UVI meters refer to http://www.niwascience.co.nz/uvozone/uvi-display .

Figure 6: Two glass canopies of terraces.

For budgetary reasons, instead of one large canopy, two smaller canopies were installed. The structures were placed 3.8m apart with structure and detail to enable an infill section to be fitted later.

Figure 7: A sand-blasted pattern creates a decorative shadow pattern under the canopies.

The built canopies were less deep (6.8m compared to 8m). In an interview, the architect Erin Tennent confirmed this change was due to limitations of the desired structural design. The north edge tilted upwards (with an area of shade fabric) thereby increasing the height at the northern edge (3.7m compared to 2.7m). The architect confirmed that at this height the colourful striped fabrics could be seen above the wall to the street. It was also considered that the shade fabric would provide a variety of shade types. On the request of the City Council, instead of clear glass, the laminated glass was sand-blasted with a fern pattern. This pattern decorated the glass roofs of bus shelters throughout the city and was considered successful in creating an attractive shadow and also concealing dust and dirt on the glass.

5. CASE STUDY OBJECTIVES & METHODOLOGY

The City Council were implicitly promoting the shade canopies, but did not have any evidence of how safe they were or of user satisfaction. To answer these questions, the research included a physical survey and a user survey.

5.1 UV levels at the site

In order to confirm the environmental effectiveness of the new canopies the following hourly measurements were undertaken between 11am and 5pm on a clear sunny day, 18 February 2006.

Firstly, the plan location of the direct shade produced by the canopies was physically plotted. UVI readings were recorded from the pool UVI meter. This prototype uses a filtered silicon carbide photodiode (the same as used in digital UV radiometer model 6.5 by Solartech Inc) [12], with diffuser, mechanical movement, and electronics by NIWA and graphics and exterior design by Tasman Studios [13]. The UVI was measured at points on a 7 x 10 point grid surrounding and under the canopies using a hand-held UV Index meter (Solartech Inc Model 6.5) held vertically at 300 above the surface.

At three locations; in full sun, under fabric shade and under glass shade (all on the grid) the following environmental measures were taken - globe temperature, wet and dry bulb temperature, wind speed and surface temperature.

5.2 User survey

32 pool users were interviewed in order to ascertain user reaction to and their understanding of the canopies.

6. FINDINGS

6.1 Location of canopy shadow

The terraces remained un-shaded until the direct shade of canopies reach the lowest step at 11.30am. Over the afternoon the terraces were well shaded, with half the steps still in the shade at 5pm.

6.2 UV protection

At solar noon (1pm) when the UVI in the open measured 7.5, the UVI under shade of the canopy varied from 1.3 in the centre to 2.0 on the edge. Protection factor (PF) is the UVI in the open divided by UVI under the shade. Findings were analysed to

understand how PF varied in the various locations as presented in the following chart.

Table 1: Average protection factors (PF) at grid points with the following conditions throughout the day.

PF (average)	Time	11am	Noon	1pm	2pm	3pm	4pm	5pm
	UVI	4.5	6.7	7.5	7.7	6.6	5.2	3.5
In direct sun	In open	1.0	1.0	1.0	1.0	1.2	1.6	1.4
	under canopy	1.2	1.1	1.1	1.2	1.5	1.9	1.6
In shade	In open	n/a	3.3	3.3	3.6	4.1	3.9	1.6
	under canopy	3.2	4.3	4.5	5.1	5.6	6.4	4.2

As the reference, UVI was measured on the pool meter. As indicated on Table 1, during the middle of the day there was a good correlation between this measurement and the hand-held meter positioned in direct sun locations. The rise in PF values after 3pm is probably due to the enclosure around the detector on the hand-held meter shielding the direct sun at low angles. In comparison, the detector on the pole was fully exposed to direct sun at all angles. This factor would therefore overvalue all protection factors after 3pm.

6.3 Wind speed

Light variable breezes of 0.4 – 1.8 m/s were recorded consistently in hourly measurements.

6.4 Temperature

Between 11am and 5pm, dry bulb air temperature varied 21 -23°C, with relative humidity of 81%.

Globe temperatures ranged: in full sun (35-38.5°C), under glass (26.5 – 29.5°C) and under fabric (23.5 - 28°C). On average, under glass was 3°C warmer than under fabric and 9°C cooler than in full sun.

Between 11am and 5pm surface temperature of the concrete terraces averaged 41°C in the direct sun and 28°C under fabric or glass shade

A series of spot globe temperature measurements firstly in the shadow of the sand-blasted areas of glass and secondly under clear glass recorded an average +5°C difference.

6.5 User questionnaire

On clear sunny days 18 & 22 February 2006, between the hours 12.45pm and 4.35pm, 32 pool users (11 male and 21 female) aged between 10 and 70 years were interviewed. 19 were seated in direct sun and 13 under glass or fabric shade. 62% of those in shade had chosen to sit out of the full sun. Their reasons included they didn't like sunscreen or did not have it with them and did not want a tan or to burn. 89% of those in the direct sun had chosen not to sit in the shade. Of these, only 18% wanted a tan, but 65% chose to sit in the full sun to enjoy its warmth. Generally interviewees were comfortable, 88% of all users described their comfort level as neutral or warm.

28% of pool users said they would like to get a suntan while sitting by pool. 72% said they were wearing sunscreen.

Users were asked to estimate their expected time of relaxing by the pool. Based on this estimate, the UVI at the time and the protection factor of their chosen location (either in full sun or under shade), the amount of UV exposure was estimated for each user. This exposure is measured in standard erythema dose (SED) [14]. The following chart displays the results in two groups, those wearing sunscreen and those not. Each histogram column represents the estimated SED received by each of the 32 interviewees if unprotected by sunscreen.

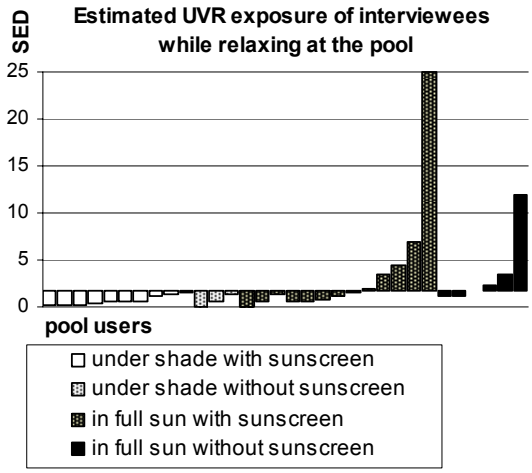

Figure 8: Estimated UVR doses of interviewees based on their expected time relaxing and the UVI. The X axis is set at 1.8 SED, the dose required to cause erythema or sunburn in people with sensitive skin. Estimations do not include the affect of sunscreen.

SPF 15 sunscreen, correctly applied, would reduce UV exposure by 15 times, e.g. 25 SED would be reduced to 1.7 SED. Therefore, considering only the time relaxing around the pool (not swimming), two interviewees might have experienced sunburn. These included a teenage boy, not wearing sunscreen and sunbathing to 'get a tan' and a school girl fully clothed watching her class-mates swimming but not wearing sunscreen. She had chosen to sit on a seat and all seats were in full sun. Assuming a well tanned middle-aged man re-applied his sun-screen for his 6 hours of sunbathing, he might have been protected.

97% of those interviewed guessed that the City Council had erected the canopies for sun-shading, although 15% thought rain or wind shelter may also have been a reason. 34% did not think or were unsure that the glass would be providing UV protection and 72% thought the canopies would have a protection factor of 2 or less. After being told that the canopies gave protection PF 4 – 6, 69% said they would consider sitting under them in the future.

7. DISCUSSION

7.1 UV protection

Shade structures of PF 15 are advised for all day protection [2], but the user survey confirmed that pool visits were typically short, with the majority of users wearing sunscreen and very aware of the danger of UV over-exposure. The user survey confirmed that most users are aware of the need for UV protection and would were sunscreen when swimming in an open air swimming pool. Pool side shade could reasonably be expected to complement personal protection. At solar noon in mid-summer (UVI 12), shade of protection factor PF (6 - 4) would take 44 – 66 minutes to affect 1.8 SED (assuming sunscreen is not used). 81% of those surveyed reported relaxing times less than 40 minutes.

It is likely that users may not distinguish the difference between shade under canopies and canopy shadow open to the sky, yet protection factors vary significantly. In the survey the average protection factor of shade under the canopy was PF 4.8 while the average protection factor of canopy shadow open to the sky was PF 2.8. These findings are in line with previous research that found that 'minimizing the area of sky in view, significantly reduces scattered UVR' [15].

The UVI pool meter, in providing real time UV levels is educating the public about the changes in intensity of UV daily and during the summer season. Although almost all interviewees assumed the new canopies must be for providing solar protection, many were unsure about whether glass could shield UV and greatly under-estimated the amount of UV protection provided by the canopies. The challenge is to educate the public about this new 'warm shade' typology. This could achieved by a display from a second real–time meter situated under the canopies or a 'rule of thumb" estimation e.g. PF 5 in the middle to PF 3 at the edges.

7.2 User comfort

The prime reason for pool users to choose a spot in the direct sun was to enjoy the sun's heat, especially after 'cooling off' from swimming. The glass, sand-blasted for decoration, reduced the globe temperature readings considerably. Preliminary tests suggest the use of clear glass could raise the globe temperate by at least 5°C. As the surface temperatures would also be raised, the comfort level would be warmer and therefore the canopy shade would be more likely to be used. As a climate analysis in a neighbouring coastal location in central New Zealand confirmed that cooling breezes are available 88% of the time when UVI > 2 [9], it is unlikely the space would ever be too hot.

7.3 Sun-bathing

The idea of sun-bathing is linked with skin tanning, yet only 28% of interviewees desired a suntan. Canopies of laminated glass or polycarbonate (both 99% barrier to UVR) can create outdoor environments where people can enjoy sun-bathing without risking UV over-exposure, damage to their skin or the need for regular and thorough applications of sunscreen.

7.4 A new architectural typology

The process of adapting the design of built environment to better suit the user's needs is notoriously slow. A 150 year historical review of outdoor living spaces in New Zealand found a surprisingly slow response by architects to designing appropriately for local climate [16]. It is perhaps not surprising that the implications of changes to the recommended design specification of the UV protective canopies were not recognised by the architect or the client. Firstly, a change in the canopy profile caused the lack of shade over the terraces in the morning and secondly the sand-blasting of the glass caused a reduction in thermal comfort under the canopies. This example highlights the need for case studies and education of design professionals on the design of UV protection and user comfort in out-door spaces.

The problem of cleaning glass roofs was raised by the architect (who promoted concealment of dirt by patterning) and also the pool staff (who were concerned how it could be cleaned safely). Dirt and dust on the glass also would reduce heat transmission. Further research is required on these issues.

8. CONCLUSION

In summary, the shade under the as-built glass canopies at Thorndon provides adequate UV protection for typical usage in the afternoons during the months October and February. Alterations from the recommended shade dimensions mean no shade is available over the terraces until after 11.30am (when UVI is 6). As the protection factor in the centre of the canopies is higher than on the periphery, the erection of an infill panel between the two separate canopies would provide more higher quality UV protection.

Over half of the pool users who chose to sit in direct sun did so to feel the warmth of the sun's rays. Sand-blasting of a pattern in the glass reduced the globe temperate by approximately 5°C. In order to provide 'warm shade' it is recommended that infill panels be clear rather than sand-blasted glass panels.

Public education on the protection rating of shade canopies in general and laminated glass in particular is required.

Finally, with the majority of pool users seeking warmth of the sun when UV levels require to be filtered there is definitely a role for laminated glass (or polycarbonate) canopies in providing safe sun-bathing environments.

ACKNOWLEDGEMENTS

Christina Mackay, Faculty of Architecture and Design, Victoria University of Wellington would like to acknowledge: Jonathan Delich, Manager of Thorndon Summer Pool and his staff in supporting and assisting in this research; Erin Tennent of Hunt Davies Tennent Architects for his interview; Quentin Jackson for assistance in 3D CAD analysis and Dr Richard McKenzie for his review of the draft paper.

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