Solar shadings in contemporary New Zealand architecture: state of the art and future perspectives

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ABSTRACT
With a large portion of buildings clad with translucent surfaces, solar shading is becoming increasingly important. Internationally, a great deal of research has been dedicated to this topic. In the face of climate change, New Zealand, like other countries in the world, is paying attention to this topic, which, however, is often considered a secondary aspect of the design process. This is reflected in the design of some buildings, especially residential developments, where there is a lack of consideration of optimal orientation. This research aims to extend our knowledge of state-of-the-art solar shadings in contemporary New Zealand architecture in order to determine what possible future improvements might be. In total, 339 products and 215 façades built between 2005 and 2021 were studied to achieve this objective. Results showed need for more training on solar shading design, a focus on better passive design and improved dynamic control.

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1. Introduction
Over the last 120 years, the ratio of translucent office building envelopes has increased significantly (Valitabar et al. 2022). Despite the exceptional performances obtained with low-e glass, the thermal insulation property of glass is very low in comparison to mass opaque building materials (Amirkhani et al. 2019). The larger the transparent portion of the building’s envelope is, the more important the control of solar energy inflow is, in order to keep thermal and visual conditions indoors within acceptable levels (Mandalaki and Tsoutsos 2020). As a consequence, glazed façades need an additional control system that helps avoid solar radiation during summer while allowing enough thermal loads during winter and ensuring comfortable visual conditions during operating hours (Pesenti et al. 2015). In office buildings in New Zealand, the use of large, glazed façades is also typical. In addition, New Zealanders love large openings in residential buildings to admire the view over the landscape, whether urban or rural (Hawkes 2020). New Zealand territory, especially in the north, has a sub-tropical climate with annual sunshine hours averaging 2000 in many areas (NIWA 2022). For these reasons, solar shading of façades is very important in New Zealand. The New Zealand housing crisis is worsening and demand for housing is growing (Ministry of Social Development 2022). There could be up to 27,000 new homes built in Auckland’s suburbs over the next five to 16 years (Bell 2022). The market does not appear to attribute the appropriate value to designs that follow sustainable best-practices (Garbarczyk 2021) and some new residential developments have been criticized due to a lack of attention to building orientation (Boarin, Allen, and Haarhoff 2019). All these issues show the need for a better understanding of solar shading design in New Zealand buildings and what kind of actions should be taken to improve the current and future building stock.

1.1. Objectives
The goal of this research is to extend our knowledge on state-of-the-art solar shadings in contemporary New Zealand architecture. A further aim is to identify areas of improvement that can be further studied, potentially on a case-by-case scenario. The main research question of this research is: ‘What is the current state-of-the-art of solar shading design in New Zealand contemporary architecture and how can we contribute to its improvement?’

2. Theory
The Building Research Association of New Zealand (BRANZ) found that the large areas of glazing used in New Zealand buildings mean that summer overheating is a regular occurrence (BRANZ 2011). Along with many others (e.g. Bunning and Crawford 2016), BRANZ states that the most effective way to prevent overheating through solar heat gain is to intercept the sun’s rays before they hit the windows (BRANZ 2011). For this reason, only external solar shadings are effective (Lechner 2009) and are the focus of this research. In New Zealand, solar shadings are not compulsory but recommended for summer shading and glare control. In other countries, solar shadings may or may not be compulsory. For example, in Italy, in 2009, external solar shadings were made mandatory in four cases: new constructions, complete renovations or demolitions and reconstructions.
of buildings with a usable floor area (UFA) greater than 1000 m², volumetric extensions exceeding 20%, and total renovations of the building envelope (Decree of the President of the Republic 2 April 2009, n. 59). In 2021, ES-SO, the umbrella organization for the professional solar shading associations within the EU proposed external dynamic solar shading as a mandatory European measure for climate neutral buildings (European Solar Sharing Organisation 2021).

2.1. Solar shading types and operability

BRANZ recommends preventing the sun reaching north-facing windows between 11:00 am and 4:00 pm in summer and early autumn and keeping west-facing windows shaded in the late afternoon. It also recommends using adjustable, retractable, or removable solar shadings in order to maximize solar heat gain in winter (BRANZ 2011). The new Building Code Clause H1 on Energy Efficiency (2021), which is dedicated to buildings greater than 300 m², excludes internal shading devices such as blinds, drapes, and other non-permanent window treatments from the verification methods for energy efficiency, as well as trees and vegetation (Ministry of Business Innovation and Employment 2021b). Bunning and Crawford (2016) carried out an extensive study on static and adjustable solar shading systems for office buildings in Australia. Results showed that the combination of external venetian blinds (small louvres) and the adjustment of slat tilt according to sun position and sky condition, delivered substantial energy savings when compared to a static overhang and static internal venetian blinds. In comparison to static external shading systems, the ability to make adjustments to slat tilts showed significant results in energy savings of 24.9% in Melbourne and 24.0% in Brisbane. Stazi et al. (2014) compared different external solar shadings to assess energy saving and thermal comfort. The selected location was the Marche Region in Italy and the façade was facing south-west. During summer, aluminium sliding panels, and aluminium louvres significantly lowered the temperatures of the internal glass surface. In winter, aluminium louvres, aluminium persiana, and wooden persiana were compared. Results showed that the two aluminium shadings had a very similar behaviour, while the wooden one, thanks to its insulation properties, presented higher temperature values during the night-time and slightly lower in the middle of the day, which was a recommended behaviour. The authors stated that the wooden shading device could be a good compromise for the different evaluated aspects with significant benefits for indoor comfort conditions. They also recommended making the aluminium devices adjustable (Stazi et al. 2014). The outer side of the shading devices can be integrated with PV systems to help limit the overall energy consumption of office buildings in two ways: by reducing direct solar gains during the overheated period and by producing electricity to be utilized for the function of cooling, heating, and lighting systems (Mandalaki and Tsoutsos 2020). In general, as per façade claddings, the faces of the shading devices should be of a light colour (e.g. white, cream, light grey, silver). These colours reflect light much like glazing with the angles of incidence and reflection being equal. Rough white surfaces, on the other hand, send light in all directions and this can reduce the heat island effect of cities in hot climates. The angle of the louvre blades can increase the amount of radiation returned to space (Lechner 2009; Doulos, Santamouris, and Livada 2004). CIBSE clarifies that, for horizontal external louvres the solar energy transmittance (g) depends on the angle of the louvres as well as their colour. For each slat angle and all façade orientations, light coloured louvres (with 0.6 reflectance) generally produce a lower g-value than dark-coloured ones with 0.1 reflectance (Littlefair and Butcher 2006).

2.2. Solar shadings in New Zealand

In 2012, based on NIWA (National Institute of Water and Atmospheric Research) predictions, a general trend of increasing temperatures in New Zealand, exacerbated by Global Warming was reported (Byrd 2012). In areas of the North Island, building energy use was shifting from a net heating load to a net cooling load, which increases the overall demand on electricity but also contributes to peak demands of electricity in the summer (Byrd 2012). Data indicated that energy required for cooling would exceed that for heating by 2040 (Byrd 2012). To reduce or eliminate the need for air conditioning, Byrd (2012) recommended the use of external solar shadings. Types of New Zealand external solar shading identified by Byrd were as follows: outriggers (a), shelves (b), horizontal (c) and vertical (e) louvres, and egg-crate louvres (f). Other recommendations were as follows: external louvres or canopies should be ‘lightweight’ to avoid them storing heat during the day and releasing it during the night; carefully design shadings on east and west façades because complete shading on east and west sides also means complete obscurity. Byrd (2012) also pointed out that in cities, solar shading has to be designed according to the shadows projected by the surrounding buildings. In Auckland Central, according to the orientation, the solar energy available on the vertical surfaces is less than half that on the roofs. In the ‘Guidelines for shade planning and design’ the New Zealand Cancer Society highlights the importance of designing solar shading to reduce skin cancer in New Zealand, as Australia and New Zealand have the highest incidence of Melanoma and Keratinocyte Skin Cancers in the world (Gordon et al. 2022). In the southern hemisphere, from 21 March until 23 September, the sun rises to the north of east and sets to the north of west. From 23 September until 21 March, the sun rises to the south of east and sets to the south of west. In New Zealand, sunshine hours are relatively high in areas, such as Marlborough, Nelson, Bay of Plenty, Gisborne, Hawke’s Bay, and inland areas of both south Canterbury and Otago. Areas exposed to prevailing air-streams, such as Fiordland, and the Southland and Otago coasts, tend to be cloudier (Greenwood, Soulos, and Thomas 1998). Northern New Zealand, including Auckland, has a sub-tropical climate with annual sunshine hours averaging 2000 in many areas. According to the New Zealand Cancer Society, shades should be available from September to April. The summer UVI is often extreme. Autumn and spring UVI values can also be high. The Wellington area has similar characteristics while in Christchurch, shade should be available from September to March. The Cancer Society identifies different solutions for outdoor living as well as basic solutions for façade design (Greenwood, Soulos, and Thomas 1998).

GreenStar is the Green Building rating tool for office buildings in New Zealand. Its technical manual includes an accurate evaluation of external solar shading for credits achievement. Different devices are assessed according to their configuration: fixed shading devices, manually controlled solar shading
devices, and automatically controlled shading devices. Internal shading devices are not considered for HVAC simulation or for energy calculation (NZGBC 2017).

Another important aspect of sustainable architectural design in New Zealand is the implementation of indigenous design principles. The importance of embedding cultural narratives into projects including, e.g. identification of mana whenua (territorial rights); significant landmarks and artwork; and local korero (information) for visitors is being acknowledged in several new projects (Raerino et al. 2021). Architectural designers, like Jade Kake, highlight that the visual expression of building structure is an inherent aspect of Māori architecture, which can be evidenced in newer projects. Structural elements can be carved not only for decoration, and also new technologies like 3D printing and other digital fabrication tools can be used to produce sculptural work and building-integrated elements that communicate indigenous values (Kake 2021). As a consequence, solar shadings design can be part of this process, as, for example, in the Te Wānanga o Raukawa façade in Ōtaki (designed by Tennent Brown Architects) which relates to Māori cosmology and local history (Archipro Editorial Team 2019).

3. Methods

To respond to the research question, two surveys were carried out: a survey on solar shading products available in New Zealand and a survey on the façade design of buildings designed by eminent local designers and located in New Zealand. Site visits were carried out to refine data collection. Results were then compared to relevant literature.

3.1. Survey on solar shading products

The first survey involved a research on solar shading products available in New Zealand. The aim of this survey was to identify the products available locally, both manufactured/assembled in New Zealand and imported, to better understand their application in local architectural design. This survey utilized four different product libraries available in New Zealand: Miproducts, EBOSS, ArchiPro and Productspec. These online databases provide performance information, compliance information, drawings, case studies, and technical advice from several leading New Zealand suppliers (EBOSS 2022). This first survey included the technical information outlined in Table 1. Table 1 also shows the different options available for each research criterion. Membranes include different types of shading devices: awnings and blinds made of fabric plus various types of lightweight canopies and covers (Bellia et al. 2014).

3.2. Survey of case studies

The second survey involved buildings built within New Zealand. Case studies had to present external solar shadings on one façade at least. Buildings built between 2005 and 2021 were chosen in order to better understand recent trends in architectural design. Buildings were medium-to-large scale residential, commercial, or mixed use. Buildings had to be designed by eminent local designers for an easier access to resources. In order to identify relevant case studies, the research team utilized local architecture magazines and online resources. In particular, the magazine Architecture NZ (2005–2021) and its website Architecture Now were examined to identify case studies. In addition, more than 50 official websites of local architecture offices were scanned. The research team initially identified 162 façades of interest in the South Island, then limited these to 58, and more than 200 façades in the North Island, then limited these 136. The limitations were due to solar shadings not meeting the above criteria, and many residential buildings that could not be located to identify their correct orientation. The final survey included 215 façades. Each façade was studied according to a set of criteria derived from relevant literature as outlined in Table 2. To complete and confirm the results of this investigation, site visits were carried out between April 2022 and May 2022 in three major areas of New Zealand: Auckland, Wellington, and Christchurch. In this period, 163 façades out of 215 were visited (76% case studies) in order to collect information not available in the literature. Façade approximate orientation was identified by using Google Maps and by verifying the buildings’ orientation on-site by using a digital compass.

4. Results

4.1. Products

In total, 339 products were identified in four different New Zealand product libraries/database, including Miproducts (132

| Research criteria                  | Options                          | Other options                     | References                  |
|-----------------------------------|----------------------------------|-----------------------------------|-----------------------------|
| Region and country                | Asia, Europe, North America, Oceania | Turkey, China, Belgium, Germany, Italy, Spain, UK | (Miproducts 2022) (EBOSS 2022) (ArchiPro.co.nz 2022) (Productspec 2022) |
| Type of solar shading             | Louvre, membrane, screen, shelf, shroud, shutter | Composite, fabric, glass, metal, plastic, timber | (Baker and Steemers 2014) (Lechner 2009) (Manav 2017) |
| Material of the shading elements  | Composite, fabric, glass, metal, plastic, timber | RGB values (as described by the manufacturer) | (Ministry of Business, Innovation and Employment 2021) |
| Colour                            | Residential, commercial           |                                   | (Premier 2019)              |
| Intended use                      | Static, Adjustable                | Actuation: manual, motorized      | (Byrd 2012) (Mangkuto, Rohmah, and Asri 2016) (Raerino et al. 2021) |
finds), EBOSS (119 finds), ArchiPro (85 finds), and Productspec (3 finds). Some products were included in more than one database, hence duplicates were excluded. In the first stage the research focused on Miproducts and EBOSS libraries which explains why ArchiPro and Productspec presented less finds. In total, 87% of the products identified are manufactured in Oceania, 10% in Europe, and the rest in North America (3 finds) and Asia (4 finds). Of the products manufactured or assembled in Oceania, 84% are manufactured in New Zealand and 16% in Australia. Of the total, 74% identified products are manufactured or assembled in New Zealand. Imported European products (35 finds) come from Germany (18), Italy (10), Spain (5), UK (1), and Belgium (1).

In total, 51% of products are louvres, 36% membranes, 8% screens, 2% shelves, 2% shutters, and 1% window shrouds. Of products manufactured in New Zealand, 62% are louvres, 31% membranes, 3% shelves, 3% shutters, and 1% window shrouds. All shelves and window shrouds are manufactured in New Zealand. All identified screens are Australian products. The majority of products have shading elements made of metal (59%) and they are mainly louvres. Fabric products are 29%, timber and plastic products 4%. Table 2 provides an overview of solar shading products and related materials.

In total, 43% of products are adjustable (dynamic) and 29% are static; 28% can be supplied either as static or adjustable devices. Table 4 shows solar shading types in relation to their operability: louvres can be either static or dynamic; membranes are mainly adjustable; all screens, shelves, and window shrouds are static; shutters are generally adjustable. Adjustable solar shading devices are mainly membranes and louvres (Table 4). In total, 27% of products are motorized adjustable shading devices and 9% are only manually operable. Most adjustable shading devices can be supplied either with manual or motorized operation (64%).

Almost all products can be supplied in any colour. 25 products (glass and plastic) are translucent. For some products, specific colours or ranges are indicated: a manufacturer of wooden screens (8) provides the following colours: American Oak, Spotted Gum, Dark Oak Premium, Tasmanian Oak Premium, Premium Oak, Kiwi Black Premium, Golden Oak Premium, Iron Bark, Teak, Weathered Wood, Western Red Cedar, Ebony, and Urban Oak. A manufacturer of aluminium louvres (23) provides the following colours: Whitewood, Chestnut, Siberian-Larch, Snowgum, Bushwood, Blackwood, and Driftwood.

In total, 49% of products are dedicated to residential and commercial architecture; 29% to residential buildings only; 16% to residential, commercial, and industrial architecture; and 6% to commercial architecture only.

Windows are considered small-medium when WWR (window-to-wall ratio) is between 20% and 40%. Windows that cover more than 40% of the façade are considered ‘large’ (Mangkuto, Rohmah, and Asri 2016). Office buildings often have large windows. The majority of products are designed for large windows/openings (62%). In total, 31% of products can be supplied in different sizes to fit a wide range of purposes, while 7% of products are designed only for standard residential openings (e.g. detached houses).

In total, 43% of products can be installed either parallel to the façade or projecting from it; 38% is cantilever only (e.g. fixed shelves); 19% is parallel to the façade (e.g. horizontal louvres, vertical fins, screens). Indigenous design principles were not identified in any of the studied products. Figure 1 shows the

| Table 2. Research criteria for case studies. |
|---------------------------------------------|
| Research criteria | Options | Other options | References |
| GPS coordinates | Latitude and longitude | North, North-East, East, South-East, South, South-West, West, North-West | (Google 2022) (Google 2022) (Ministry of Business Innovation and Employment 2021a) |
| Façade orientation | North, North-East, East, South-East, South, South-West, West, North-West | | (Baker and Steemers 2014) |
| Climate zone | 1, 2, 3, 4, 5, 6 | | |
| Type of solar shading | Awning, Eggcrate, Fin (vertical), Louvre (horizontal), Outrigger, Screen, Shelf, Shroud | | |
| Material of the shading elements | Ceramic, Composite, Concrete, Fabric, Glass, Metal, Timber | | |
| Colour | RGB Hex codes (Adobe Photoshop) | | | |
| Intended use | Residential, commercial | | |
| Operability | Static, Adjustable | Actuation: manual, motorized | (Premier 2019) |
| Alignment with the facade | Parallel, cantilever | | | |
| Window type | Small-medium, large | | |
| Indigenous design principles | Present, absent | | (Raerino et al. 2021) |

| Table 3. Solar shading products and their materials. |
|---------------------------------------------------|
| Louvre | Membrane | Screen | Shelf | Shroud | Shutter |
| Composite | 1 | 1 | – | – | – | – | 2 |
| Fabric | 2 | 97 | – | – | – | – | 99 |
| Glass | 2 | 3 | – | – | – | – | 11 |
| Metal | 164 | 10 | 17 | 2 | 2 | 6 | 201 |
| Plastic | 2 | 12 | – | – | – | – | 14 |
| Timber | 3 | – | 8 | – | – | 1 | 12 |
| TOTAL | 174 | 123 | 25 | 8 | 2 | 7 | 339 |
number of products identified according to their installation and visualizes their alignment with the façade.

4.2. Case studies

The case studies comprised 215 façades belonging to 194 different buildings. Some buildings presented more than one façade integrated with solar shadings that were relevant for the research. Most façades belong to commercial buildings (72%), while 27% belong to residential buildings (communal or single dwelling) and 1% are mixed use (commercial and residential). As per the Building Code Update 2021 proposal, New Zealand is divided into six climate zones (Ministry of Business Innovation and Employment 2021a). In total, 51% of façades are located in climate zone 1 (Auckland area), which is the most populated area of New Zealand (approx. 43% of the entire population); 26% are located in climate zone 5 (Christchurch area, which has 16% of the population); 10% are in climate zone 3, (Wellington area, which has 15% of the population); 7% are in climate zone 2 (16% of the population); 4% are in climate zone 6 (4% of the population); and 2% are in climate zone 4 (6% of the population). Table 5 shows the number of façades identified in each climate zone.

Each building/façade was identified with its own GPS coordinates (latitude and longitude) and street address. In total, 45% of façades are in Auckland and 22% are in Christchurch. The city of Christchurch has been largely re-constructed following the earthquakes of 2010 and 2011. In total, 5% of façades are in Wellington; 4% are in Hamilton; and 22% are in other towns.

Figure 1. Installation: alignment with the façade (products).

Table 4. Solar shading products and their operability.

| Louvre | Membrane | Screen | Shelf | Shroud | Shutter |
|--------|----------|--------|-------|--------|---------|
| Static | 45       | 19     | 25    | 8      | 2       | 99      |
| Adjustable | 35 | 103    | –     | –      | –       | 6       | 144     |
| Static or Adjustable | 94 | 1    | –     | –      | –       | 1       | 96      |
| TOTAL  | 174      | 123    | 25    | 8      | 2       | 7       | 339     |

Most façades are oriented towards the north (27%); 18% towards the east; 16% west; 13% north-west; 11% north-east; 6% south-east; 6% south; and 3% south-west. In the southern hemisphere, to make the most of the sun for warmth and natural light, rooms that are used frequently should face north. The main glazing should also face north (Greenwood, Soulos, and Thomas 1998). Table 6 shows the relationships between climate zone and façade orientation. In zone 1, 29% of façades are facing north, 23% are facing east, and 11% are facing west. In zone 2, 50% of façades are facing north, 13% are facing east and 13% are facing south-west. In climate zone 3, 29% of façades are facing east. In zone 5, 25% of façades are facing west, 23% are facing north, and 18% are facing north-west.

The survey identified 9 different types of solar shadings: awning, eggcrate (composed of vertical and horizontal elements), vertical fin, horizontal and vertical louvre, outrigger (cantilever louvre), screen (e.g. meshes), shelf and window shroud. The most frequent solar shading type is the louvre (42%), followed by screens (22%) and vertical fins (21%). 65 façades have horizontal louvres and 24 vertical louvres. Eggcrate façades are 9%, outriggers 3%. Shelves, awnings, and window shrouds are 1% each. Figure 2 shows the types of solar shading in relation to the orientation of the façades. Literature best-practices are included to compare them with the results of the case studies (Sofie Pelsmakers 2012). Eggcrate is ideal for north-west and north-east façades: most are facing north, east, and west. Vertical fins are ideal for east and west façades: most are facing south-east and south. Horizontal louvres are ideal for north façades: most are facing north. Screens are

Figure 2.
ideal for north-west and north-east façades (Littlefair 2018): most are facing north and north-west.

Most solar shadings are made out of metal (80%) and 15% are made of timber. In total, 2% are made of concrete; 1% are fabrics; 1% ceramic; 0.5% composite and 0.5% glass. Table 7 shows the different shading types and related materials. Metal is widely used in louvres, fins, screens, and eggcrate façades. Timber is mainly used in horizontal louvres and screens.

In total, 95% of the shading devices are static and only 5% are adjustable (11 façades out of 215). Of those that are adjustable, 8 devices have manual operation and 3 devices are motorized. In total, 95% of the shading devices are parallel to the façade while only 5% are cantilever, mostly outriggers, shelves, and shrouds. The shading elements (e.g. louvres, fins, and screens) are mostly vertically oriented (53%); 38% are horizontal; and 9% are a combination of horizontal and vertical elements (e.g. eggcrate or shroud).

Colours that present an albedo higher than 0.65 can be considered ‘light’ (e.g. silver, white, and light-grey coloured surfaces); surfaces with values between 0.65 and 0.45 should be considered ‘medium’ (e.g. dark-grey, green, red, brown); surfaces with values below 0.45 are considered ‘dark’ (dark brown to blue and black) (Taha, Sailor, and Akbari 1992). Table 8 shows the results in relation to the colours of the shading elements of the case studies.

Design references to Māori and Pacific indigenous culture are declared by the designers in 28 buildings out of 194, which corresponds to 14% of the whole sample.

5. Discussion

The largest number of the products identified in this study are manufactured in Oceania. Of the total, 74% solar shading products are manufactured or assembled in New Zealand. However, this does not mean they are made with locally sourced materials to reduce their embodied energy (Morel et al. 2001). In fact, in 2021, EBOSS (an independent digital content provider for New Zealand specifiers and suppliers of architectural products) found that 90% of construction products sold in New Zealand are either imported finished products or manufactured locally from at least some imported components (EBOSS 2021). It is important to observe that solar shading devices represent a limited amount of building products out of the total available in New Zealand. They represent a small portion of the products manufactured by 30% of suppliers that fall under the ‘enclosure’ category (EBOSS 2021).

The majority of the identified products are louvres (51%) and most products are made of metal (59%). This confirms the results of the case studies survey where 42% of solar shadings are louvres and 80% of solar shadings are made of metal. One of the benefits of louvres is they can be installed parallel to the façade or cantilever, and their blades can be arranged either vertically or horizontally. Metal louvres come in different sizes and can be adapted to small or large windows. While it is not unusual to see a low percentage of plastic products (4%) (O’Brien, Kapsis, and Athienitis 2013), it is quite surprising to see so few timber products (4%) as well as facades integrating timber solar shadings (15%). Metal is widely used for solar shadings in office buildings (Ghose et al. 2017), especially for its durability and relatively low maintenance (Carlsise and Friedlander 2016). Timber has various carbon-mitigation benefits (Stocchero et al. 2017) and the timber industry is very important for the building and construction sector in New Zealand (Buchanan et al. 2008). However, in this study, the relatively low incidence of solar shadings made with timber may be related to the fact that these devices are continuously exposed to weathering and surface degradation is very likely (Bobadiilha et al. 2021).

Design references to Māori and Pacific indigenous culture are declared by the designers in 28 buildings out of 194, which corresponds to 14% of the whole sample.

Table 6. Façade orientation and climate zone.

| Zone | North | North-East | East | South-East | South | South-West | West | North-West |
|------|-------|------------|-----|------------|-------|------------|------|------------|
| 1    | 32    | 7          | 25  | 10         | 9     | 3          | 12   | 11         |
| 2    | 8     | 1          | 2   | 1          | 1     | 2          | 1    | 1          |
| 3    | 3     | 4          | 6   | –          | –     | –          | –    | 4          |
| 4    | 1     | 1          | –   | –          | –     | –          | –    | 2          |
| 5    | 13    | 9          | 6   | 2          | 1     | 1          | 14   | 10         |
| 6    | 2     | 1          | –   | –          | –     | –          | 2    | –          |
| TOTAL| 59    | 23         | 39  | 14         | 12    | 6          | 35   | 27         |

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Activity consent and these have to be produced by the façade engineering company. Hence, architectural designers may have a relatively limited role in their design. The role of BEM (Building Energy Modeling) and simulation tools is also more and more relevant in this field of design and it will become more
relevant in the future (González and Fiorito 2015). Buildings that are Green Star certified need a performance assessment of the façade to meet certification criteria and this has to be carried out by certified environmental and façade engineers (NZGBC 2017).

A large majority of products are dedicated to residential buildings and other types of buildings (94%). Only a small number is dedicated to commercial buildings only (6%). Despite this result, the majority of products are designed for the large windows (63%) that are typical of commercial buildings. This indicates a certain flexibility in the products, which is confirmed by the fact that most of them are metal louvres. The case studies survey indicates that 72% of case studies are commercial buildings and 27% residential. From this result, it can be inferred that the products on the market are mostly dedicated to residential buildings, while custom designs (non-standard products) are prevalent in commercial buildings (Thermosash 2022).
Table 7. Solar shading types and materials.

| Material       | Awning | Eggcrate | Fin (vertical) | Louvre (horizontal) | Louvre (vertical) | Outrigger | Screen | Shelf | Shroud |
|----------------|--------|----------|----------------|---------------------|-------------------|-----------|--------|-------|--------|
| Ceramic        | –      | –        | –              | 2                   | –                 | –         | –      | –     | –      |
| Composite      | –      | –        | –              | –                   | –                 | –         | 1      | –     | –      |
| Concrete       | –      | 2        | 2              | –                   | –                 | –         | 1      | –     | 5      |
| Fabric         | 2      | –        | –              | –                   | –                 | –         | –      | 2     | –      |
| Glass          | –      | –        | 1              | –                   | –                 | –         | –      | –     | 1      |
| Metal          | –      | 17       | 35             | 53                  | 22                | 5         | 36     | 3     | 1      |
| Timber         | –      | 1        | 7              | 10                  | 2                 | 2         | 10     | –     | 32     |
| TOTAL          | 2      | 20       | 45             | 65                  | 24                | 7         | 48     | 3     | 215    |

Table 8. Colours of the shading elements.

| Colours                     | Albedo      | Nr. Case studies | %  |
|-----------------------------|-------------|------------------|----|
| Whites                      | Light       | 52               | 24 |
| Very light blues            | Medium      | 97               | 45 |
| Grey                        |             |                  |    |
| Earthy colours              |             |                  |    |
| Others (medium albedo)      |             |                  |    |
| Dark grey and dark brown    | Dark        | 66               | 31 |

In total, 51% of case studies are located in climate zone 1, which is the sunniest part of New Zealand (Greenwood, Soulos, and Thomas 1998), while 45% are located in Auckland, which is the largest city in New Zealand. The comparison between the type of solar shadings and the façade orientation highlights a generally adequate approach to solar shading design. Most shaded façades are oriented towards the north (27%), northwest (13%), and north-east (11%), which is 51% of all the case studies. These façades present, in most cases (77%), types of solar shadings that are aligned with literature best-practice (Littlefair 2018). In total, 23% of case studies present solutions that are different from the literature. In particular, 6% of the façades are oriented towards the south. Of these, 67% belong to medium-density housings and only 33% to commercial buildings. This result indicates that more training is needed to implement the correct solar shading design for medium-scale residential buildings. In particular, modelling of solar shadings should be integrated in the early stage conceptual design and architectural designers should have basic knowledge of this field (Premier 2018). The result is also confirmed by other surveys carried out in New Zealand. A survey carried out on the Hobsonville Point development in Auckland showed that the design did not focus on orientation and solar shading in the early stages and therefore the masterplan did not always reflect considerations of block exposure and lot orientation (Boarin, Allen, and Haarhoff 2019). This result contrasts with the initial aims of the design that required all dwellings to be oriented to maximize solar gain from the sun, living areas were to face north to collect heat in winter, and eaves and other shading structures were required to help avoid overheating in summer (Haarhoff et al. 2019).

More professional training is also necessary in terms of colour choices. Even if light coloured and medium-coloured solar shadings are represented by 69% of the case studies, there is a very high number of dark coloured solar shadings, 31%, which corresponds to 66 case studies. These façades use metallic solar shadings in black or very dark grey and brown colours. This choice contributes to increasing the solar energy transmittance of windows, and as a consequence, it increases the indoor temperature in summer (Tällberg et al. 2019).

For a small amount of case studies (14%) designers state they have incorporated indigenous values in their design. This aspect is very important for New Zealand architectural design identity and is a positive sign of a potential future increase in this direction.

6. Conclusions

A survey on 339 products and 215 façades was carried out to expand the current knowledge on solar shadings in contemporary New Zealand architecture. The research involved only external solar shading devices and façades built between 2005 and 2021. The methodology involved a research based on local product libraries and bibliographical resources on recently built projects designed by eminent local architecture studios. Buildings were mainly commercial. Findings were supported by site visits (more than 150 façades). Data collected was organized on a Ms Excel synoptic table and statistical information was studied through this table. Results show that:

- Most solar shading products are manufactured or assembled in New Zealand;
- Louvres are the most frequent solar shading device;
- A large majority of solar shadings are made out of metal;
- Almost all solar shadings are static and not adjustable;
- Most designs follow the literature best-practices in terms of the type of solar shading and façade orientation;
- Most shading devices present light and medium albedo surfaces.

The following areas of improvement have been identified:

- Design of south facing façades should take into account the presence of smaller openings;
- More professional training is needed to implement a correct solar shading design in medium-scale residential buildings;
- Modelling of solar shadings needs to be done in the early stage design and more professional training is needed in this regard;
- More attention needs to be paid to dark coloured shading devices to reduce window solar energy transmittance (g);
- A stronger focus on low-carbon materials (e.g. timber) in the design of solar shadings is desirable in order to reduce the carbon footprint of façades;
- The implementation of adjustable solar shadings may contribute to enhancing outdoor views and winter heat gain, and an in-depth study of smart solar shading systems may contribute to reducing their overall energy consumption.
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