A report on the windcatcher

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Synopsis

This report gives a discussion on natural-ventilation systems using windcatcher; its working principles, its suitability for the Australian conditions, economic and environmental benefits from its use. Focus will be placed on the windcatchers from Monodraught Ltd of the UK.

1) Windcatcher – How it works

A windcatcher, also often called wind tower, is a device used to deliver fresh outside air to a building interior, and extract stale air from it, yet not requiring any human-made energy like electricity. As such, it is a natural-ventilation device.

In a windcatcher, the driving forces for the air flow are all natural. These arise from either a blowing wind, or a temperature difference between the building interior and the outside. Basic shape of a windcatcher and its working principles are depicted in Figure1 in wind-driven mode, and in Figure 2 in temperature-driven mode.

When a windcatcher is placed on the roof of a building, as depicted in Figure 1, a blowing wind will generate a high pressure on the windward side of the windcatcher, and lower pressures inside the building and on the leeward side of the windcatcher. These pressure differences are often enough to drive the fresh air from the wind into the building, and extract the stale interior air out, through the windcatcher's openings.

When there is a temperature difference between the building interior and the outside, the windcatcher can also deliver ventilation flow, as depicted in Figure 2. This is because hot air rises due to changes in buoyancy force on air parcels at different temperatures. In buildings or chimneys, this is called stack effect. This mode of temperature-driven ventilation through a windcatcher is especially effective during summer nights when the outside air is significantly cooler than the air inside, thanks to a much faster cooling rate for the outside air.

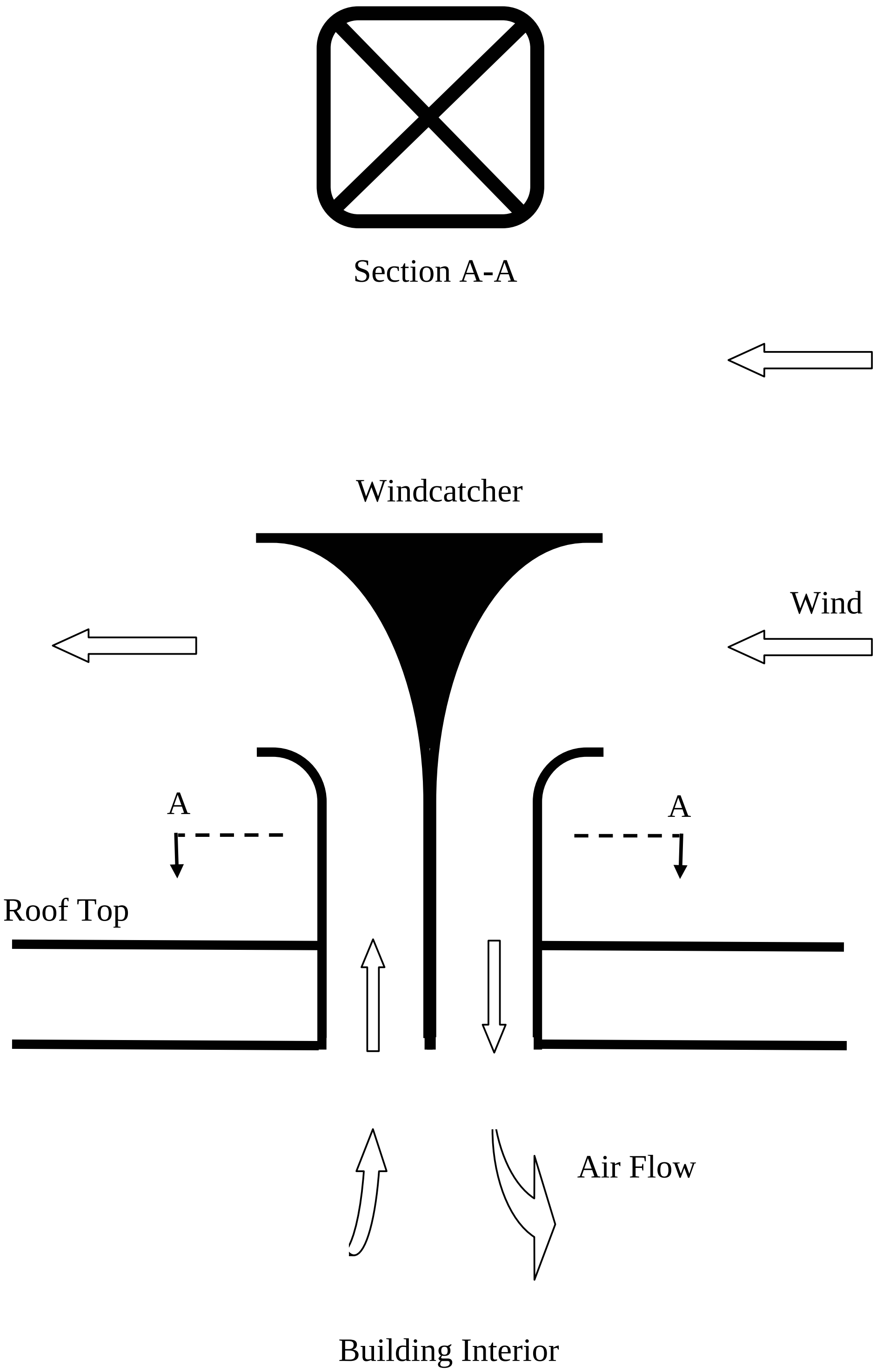

Figure 1. Ventilation flow via a windcatcher due to wind-generated pressure differences

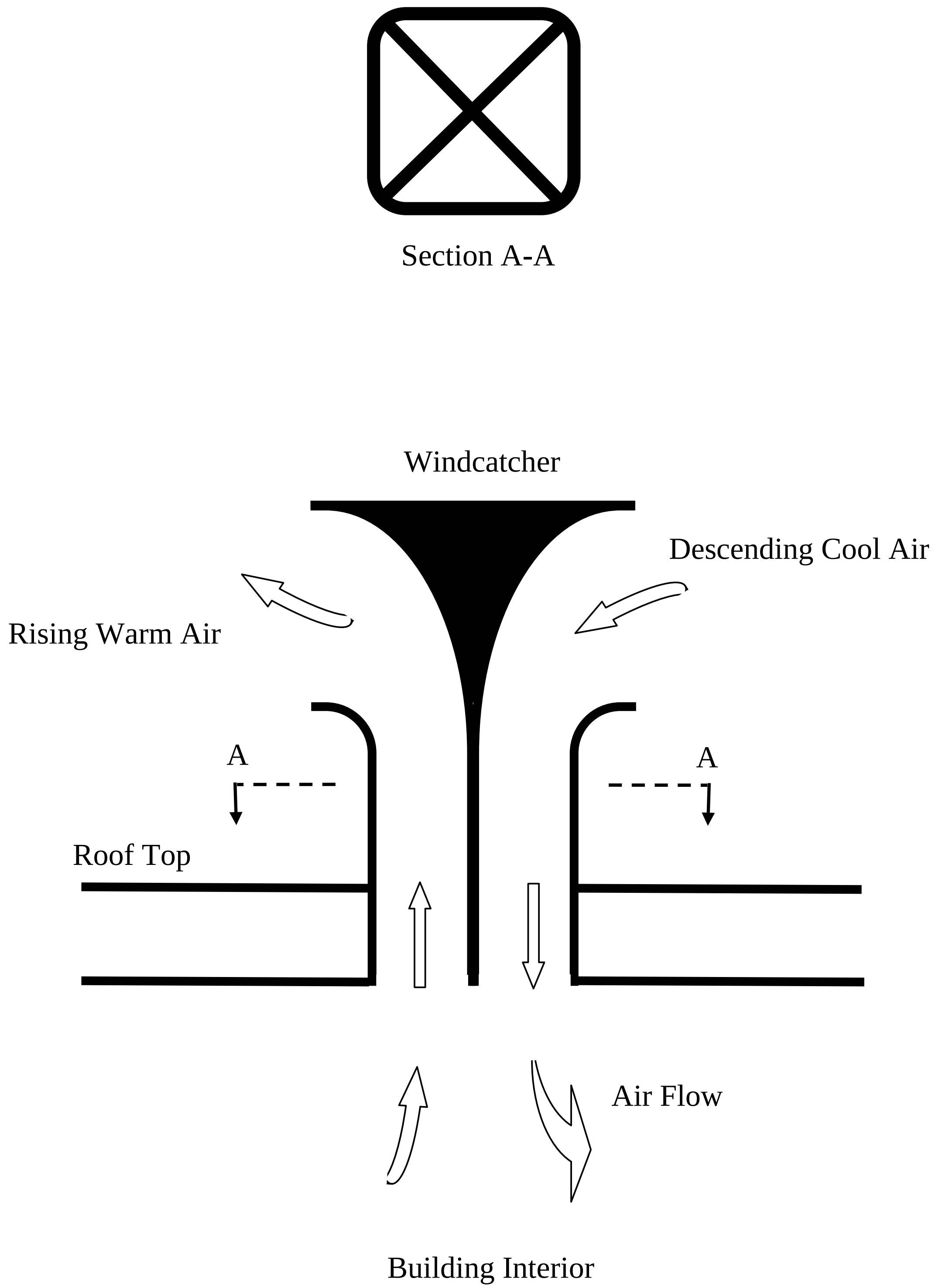

Figure 2. Ventilation flow via a windcatcher due to temperature differences.

2) The Monodraught windcatchers

Several thousand windcatchers from Monodraught Ltd have been installed on numerous buildings, especially in the UK; in particular, they are quite popular with schools. As such, they have been well accepted. Examples are those installed at St Annes School in Jersey, St Wilfreds School, York University, Sutton Arena leisure centre in Surrey, the Royal Hospital Chelsea in London, an indoor market in Bridgetown, Barbados in the West Indies, etc. [13-16]. Figure 3 shows some examples of installed Monodraught windcatchers. More details of many case studies can be seen at [16].

Monodraught also presents sample calculations and procedure for arriving at suitable windcatcher systems to meet ventilation requirements [17-18]. These include both needed fresh air supply to meet rigorous and authoritative guidance and recommendations (like those of the British Standards and Chartered Institution of Building Services Engineers (CIBSE), UK), and sufficient air flow for heat-load removal. The calculations and procedure are seen to be adequate and convincing.

In addition to the standard windcatcher systems, solar-boosted systems have also been introduced. In these, a fan running on solar-energy is incorporated with the windcatcher, to provide additional ventilation on sunny days. One installed solar-boosted windcatcher system is shown in Figure 4, with the solar panel visible on the windcatchers' top.

3) Verification and effectiveness

3.1) Air flow rate

There has been a number of scholarly work on the windcatcher as an effective natural-ventilation device [1-12]. For example, Elmualim [4] did a wind tunnel and computational modelling study of a square windcatcher of dimensions 500×500 mm and 1.5 m length. The windcatcher was apparently from Monodraught, as per the paper's acknowlegements. Measurements from this work have shown a ventilation rate of 74 l/s is achieved at wind speed of 2 m/s blowing perpendicularly onto one windcatcher side face, increasing to 101 l/s at 3 m/s wind, and 137 l/s at 5 m/s wind. When wind blows diagonally to a windcatcher face, the corresponding flow rate is reduced to the minimum of 36 l/s at 2 m/s wind, 53 l/s at 3 m/s wind, and 82 l/s at 5 m/s wind, respectively. Very little or no short-circuiting (flow passing directly from one windcatcher's opening to the other openings without passing through the space to be ventilated) has been observed.

Another rigorous four-day on-site investigation by the Building Research Establishment at the University of Hertfordshire [15] has further established the effectiveness of a Monodraught windcatcher system under summer conditions. The ventilation flow rate in a 458 cubic-meter lecture theatre (one of the two studied) was found to range from 158 l/s (1.24 ac/h) at wind speed of 1.7 m/s, to 662 l/s (5.2 ac/h) at 4.5 m/s wind.

Kirk and Kolokotroni [8] conducted air-exchange tests (using tracer gas decay) during summers 2002 and 2001 on 3 occupied UK buildings fitted with windcatchers from Monodraught (as can be recognized by their model names, namely 1200 mm square GRP, 1000 mm square GRP, and 550 mm circular ABS units, respectively). They reported that both wind and stack effects affect air exchange rate through the buildings. Among other work, Su et al [11] investigated a solar-boosted circular wincatcher from Monodraught, using both experiments and computation, while Li and Mak [10] did a computational fluid dynamics (CFD) study.

These studies have established that a windcatcher can deliver quite substantial ventilation flow even under light wind conditions. Thus by using sufficient number of windcatcher units, adequate ventilation would be obtained for most common requirements.

3.2) Indoor temperature and CO_2 level

The use of windcatcher systems like those from Monodraught provides secure night cooling. Kirk [7] conducted tests on council offices in Kings Hill, UK, in summer 2002, and reported that indoor air was cooled by up to 4 °C by night cooling, thus allowing for a fresh start to the day, and providing cooled thermal inertia to the building structures. The results are when the external temperature was high (31 °C), the indoor temperature was still several degrees lower (25 °C on the ground floor, and 28 °C on the first floor), whereas when the outside temperature was not high (below about 23 °C), the indoor temperature was only 3 °C to 5 °C above it.

Jones et al [5] examined air quality in 2 classrooms in UK, one fitted with a 800 mm square Monodraught windcatcher (the test room), while the other is ventilated by conventional opening windows. Their measurements pertaining to summers (done in May and June 2006) show that the test room was cooler than the control room by an average of about 1.5 °C. CO_2 level was also lower in the test room, 840 ppm vs 1324 ppm in the May test, and 575 ppm vs 588 in the June test. Night cooling with the windcatcher results in the test room’s peak temperature being lower than the external peak temperature by nearly 3 °C, namely 27.8 °C vs 30.5 C; the corresponding peak temperature in the control room was 28.9 °C.

In Autumn 2008, tests were conducted at the reception area of the BSRIA building of the Building Services Research and Information Association in Backnell, Berkshire, UK, to assess the performance of a Monodraught GRP 1200 Solar Boost windcatcher [12]. The building has a particularly high solar gain, and the temperature on its first floor in summer was known to have reached 40 °C with an outside air of about 28 °C. During the test, which lasted about 7 days, operation of the windcatcher was seen to lower the peak temperature in the building (measured at 5.32 m above the ground floor) from 31.2 °C to 29.5 °C (whereas at 1 m height, temperature was unchanged at 26 °C). In particular, operation of the windcatcher had reduced the CO_2 level from 1000 ppm to 508 ppm.

A recent simulation by Khan [6] using an established software for a school classroom in Sydney for February (which, along with January, are the hottest months of the year, with outdoor temperature approaching 34 °C) has shown that, allowing for night ventilation, a 1000 mm square Monodraught windcatcher with solar boost would keep the indoor temperature below 28 °C in 72% of the occupied time, and in only less than 11% of the occupied time the indoor temperature would exceed 30 °C. The temperature figures for other months (which are cooler than February) would be lower than those above. The simulation also indicates that in only about 17% of the occupied time the fresh air’s flow rate would be below 240 l/s through the classroom. This is the flow rate required to supply 30 persons with the adequate 8 l/s per person.

Figure 3. Examples of installed Monodraught windcatchers in the UK: 1000 mm square system at Imperial College (above) and 1000 mm circular-cylindrical windcatchers at St Annes School, Jersey (below)

Figure 4. An installed system of solar-boosted windcatchers from Monodraught.

4) Suitability for the Australian conditions, and benefits

Buildings in most regions of Australia need cooling ventilation for substantial time during the year, at least during the hot summer months.

The average wind speed at Sydney's Bankstown airport is 2.3 m/s (8.1 km/h) at 9 am, and 5 m/s (18.0 km/h) at 3 pm [14-16], giving an average day-time wind speed of 3.6 m/s (13.0 km/h). Thus in substantially more than 50 % of the time, there is a wind blowing at speed higher than 2 m/s. As discussed above, at these wind speeds, windcatchers have been seen to be effective in delivering adequate ventilation, when sufficient units are used.

Taking the above wind conditions as typical for Sydney and Australia, it is clear the windcatchers, and specifically those from Monodraught, are very suitable for natural-ventilation systems in this country; and these systems are free of any energy demand.

Since the windcatchers will be effective for substantially more than 50 % of the time as mentioned above, a reduction in energy consumption for ventilation and air-conditioning by at least 50% would be achieved with their use. Benefits to the environment also entail as a result of reduction in fuel-burning for power generation.

In addition, windcatchers allow cool, fresh air to enter the buildings and expel the stale interior air during the night, making the building fresh for the following day. Windcatchers are seen to be effective in helping maintain the indoor thermal comfort for building occupants, and reducing significantly the CO_2 concentration level.

The economic and environmental benefits from the use of windcatchers for natural ventilation are thus clear.

5) Conclusions

Windcatchers, and specifically those from Monodraught Ltd, have been seen to be suitable for Australian conditions, and effective in providing energy-free natural ventilation to buildings for substantial portion of time. Reduction in energy consumption for ventilation and air-conditioning by at least 50% would be achieved with their use, along with the entailing economic and environmental benefits.

Windcatchers are thus highly recommended.

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