# SUSTAINABILITY AND THE ROLE OF NATURAL VENTILATION FOR HIGH RISE BUILDINGS IN NEW ZEALAND.

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BACKGROUND
*"…it is sometimes said of those who try to persuade man of his environmental predicament that they paint a picture so gloomy and irreversible that the average citizen's response is to go out and buy a can of beer. If nothing can be done to escape the onward rush of some irreversible eco doom, then why take the trouble even to return the can? But indeed over a vast range of environmental problems, action is possible, polices are available, reversals can take place, water can run clean, the sun shine over clear cities, the oceans cleanse our human shores and harvest ripen in uncontaminated fields."* Ward and Dubois (1972).

The concept of sustainability lacks a vision of what life could or would be. Stories of impending gloom as Ward suggests above create a sense of apathy rather than action. A sense that appears to still exists today as it was back in 1972.

Moreover, such a vision is not necessarily economically based as Lovins (1994) has noted *"…that these kinds of creative "eco-capitalism" lead to a "liveable world" but they would not necessarily give us a world we would want to live in. It also takes ethics, religion and politics to do the things. Markets can not tell us how much is enough?"*

Nor does the vision of a less polluting car as Flavin and Lenssen (1994) *"...No matter how much less polluting automobiles become in the future, one thing is clear: they will not be a panacea for the world's transportation problems. Although the new technologies could greatly reduce many of the energy related problems caused by cars, they could exacerbate others, including the suburban sprawl, congestion and destruction of neighbourhoods that is rampant in so many parts of the world. This suggests that the redesign of the automobile must be accompanied by efforts to spur an array of new transport options and to change regional development patterns so as to reduce the need for travel and create more liveable communities"*. Hawken, Lovins and Lovins (1999) also support this conclusion with their observation that*"...yet as in many other contexts, the powerful technologies of resource efficiency should coexist with a keen sense of social purpose: Means cannot satisfy without worthy ends. T. S. Eliot warned: "A thousand policemen directing the traffic cannot tell you why you come or where you go." Mobilizing the ingenuity to create a better car must be matched by finding the wisdom to create a society worth driving around in—but less often."*

Where then is this vision of a sustainable tomorrow to come from and more specifically can high rise buildings be part of that vision? (High rise being defined as 10 storeys or more in height).

Rowe (1994) suggests the following "*...it would therefore seem that the time has come for a radical rethinking of design concepts for commercial buildings so that they are centred on the needs and satisfaction of individuals. Designers will recognise that occupants have needs that differ between one another and within the individual from time to time. They will therefore design control systems that permit intelligent beings to operate responsive control systems when change is perceived as necessary; and above all that allow the choice of a gentle movement of air through an open window to stir the curtains and the spirits on a fine spring day"*.

Graeme Robertson (1991) was more specific *"Although the 20% reduction of $CO_2$ emissions by 2000 as agreed by New Zealand is a good start, to achieve true sustainability we may have to reduce our per capita emissions by over 70%. This of course requires greater changes than merely improving the efficiency of buildings; it starts to seriously question the very nature of our cities.*
*But the first step is clear – reduce energy consumption. We must locate, orientate, insulate, naturally ventilate and daylight our buildings better."*

Both authors suggested (over 10 years ago) that building designers must become more active and that this vision (at least in part) involved the treatment of natural airflows or ventilation. To date, designers in New Zealand have been slow to respond, due in part to a lack of suitable tools and more recently to a perceived and developing complexity of the concept of sustainability. Peet (2000) describes this situation with his comments "…t*he emergent complex behaviour of the super system of which we are part must also be taken into account in our discourse. I am sure we all accept, however, that many of the words we use to describe this complex system are not analytically definable, especially if we work within the perspectives of post- normal science…"* Designers use to metaphors such as low energy, green, ecological, bio climatic, climate sensitive, ecological, recycled buildings, intelligent or smart buildings, healthy buildings, energy embodied, "touching lightly on the ground", the little big house and places of the Soul find that sustainability does not now mean any particular one of these but has grown to include all and more.

This view is also supported by Boyle (2004) who states that *"…the concept of sustainability has developed considerably since its introduction by the Brundtland Commission in Our Common Future. It is now used by professionals throughout society for many purposes and with many meanings, each delivering a subtly different connotation to the term. Overall, however, there is agreement that inter- and intra-generational equity are important and that sustainability of environment, society and economics are also important. The complexity of sustainability is recognised but not yet fully understood…*"

Against the above comments is the economic reality that designers face summed up by Bosley, who is reported by Stewart (1999) as commenting on the design of the Te Papa New Zealand's National Museum he stated that *"…we have choices, that is obvious. One of the problems of some projects is that the client defines a whole lot of things that limit incredibly the exploitation of what the building can be. You don't have to accept that- you just don't get the job."*

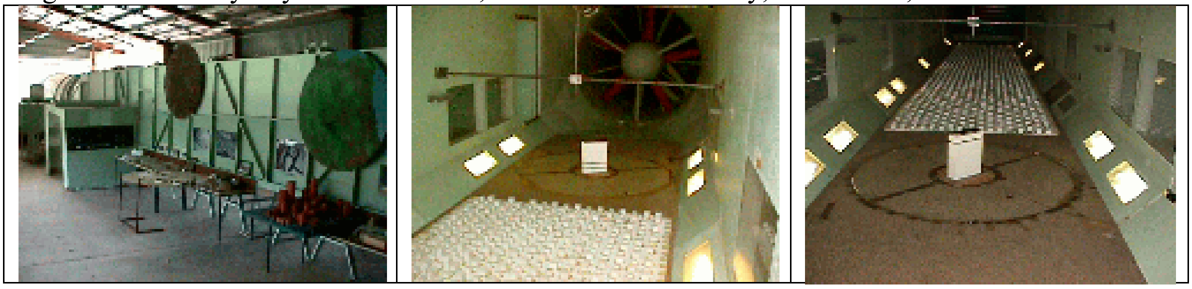
Thus, New Zealand designers appear to have not heeded the calls of Rowe or Robertson, are presumably not participating in addressing the role of high rise buildings as part of a better society (many designers would debate the place of high rise buildings in such a society) and at the same time are being marginalized from the discussion of sustainability.

This paper attempts to take a practical approach to this context. The first part applies recently developed natural ventilation tools to the climates of Auckland Wellington and Christchurch to ascertain the potential for natural ventilation in high rise buildings. The later part looks for high rise examples of buildings both overseas and in New Zealand that point to this vision for sustainability.

## DEVELOPMENT OF NATVENT TOOLS

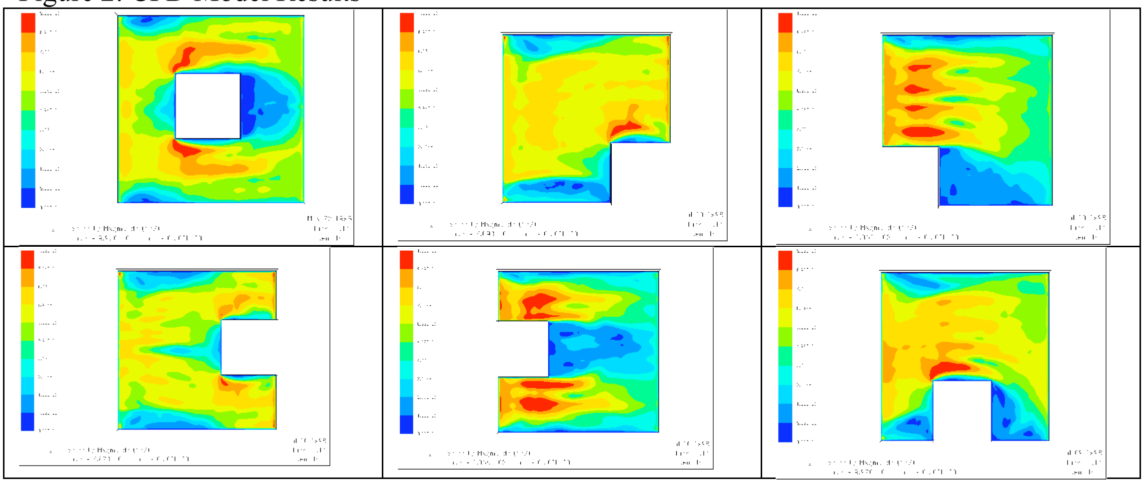
The design tool used in this study was developed from boundary layer wind tunnel (BLWT) testing and computational fluid dynamic (CFD) studies (Potangaroa, Aynsley, 1999). The BLWT at James Cook University was used and the outputs from this study were the external pressures on various high rise building forms. A typical tunnel and model set up is shown below in Figure 1.

Figure 1: Boundary Layer Wind Tunnel, James Cook University, Townsville, Australia.



The pressures from these tests were then set as the boundary conditions for various CFD simulations. These simulations studied different core and air well locations. Examples of the CFD core models are shown in Figure 2 below. In these examples a cross ventilation strategy is used (wind blowing from the left to the right) and the white centre or cut out piece represents the core area. The maximum air speeds are shown in red while the zero air speed is shown in dark blue. These air speeds are at 1.2 metres off the floor level which is approximately a person's head level when seated. The head is the most significant cooling part of the body as it is the most likely to be uncovered and hence the rational for the height.

Figure 2: CFD Model Results



Spot readings of airflows from these CFD print outs were taken as typical air speeds which when modified by the orientation of the building and climate data wind flows gave the actual airflow speed inside the building. This was used for calculation of the potential thermal comfort.

Various adaptive comfort models were investigated and the final model proposed by Auiciliens and Szokolay (1997) was adopted:

Tn=17.6 + 0.31xTm (r=0.95 for free Running Buildings)

Tm= Monthly mean temperature
Tn= Thermally neutral temperature

Interestingly this is very similar to the recent Brager De dear Model that has been adopted as ASHRAE Standard 55 which is as follows (Brager and deDear, 2000):

Tn=16.0 + 0.32xTm (for 80% confidence)

In the thermal comfort model the thermal neutral temperature is modified for an 80% or 90% confidence level, increased to allow for the beneficial cooling effects of wind flow and the decreased for the detrimental effects of humidity. The criteria suggested by MacFarlane (1958) were adopted as suggested by Aynsley (1996). MacFarlane's criteria are as follows:

- For each 10% increase in relative humidity above 60% the thermal comfort zone temperatures should be decreased by $0.8^{O}$K.
- For each 0.15 m/s increase of air speed the thermal comfort zone temperatures should be increased by $0.55^{O}$K for air temperatures up to $37^{O}$C

The tool was constructed as an EXCEL spreadsheet with separate sheets for the different areas. These work sheets functions are summarised in table 1 below.

Table 1: Structure of Spread Sheet Tool.

| | |
|---|---|
| Control Sheet | Drives the Process. Input the building's location and the building Orientation (1 to 16, 1 being north) |
| Work Area | Brings data together. If direction is 17 then % area =0, if $V_{reqd}$=0, then % is 100, otherwise the spread sheet concatenates the modified direction and the ratio of the $V_{pro}/V_{reqd}$ and then looks up the associated % area in Thermal Comfort. |
| Thermal Comfort | Calculates the % area that is above stipulated bin data values. Bin values from 0 to 2 in 0.1 increments were adequate |
| Digitised CFD Data | Spot height data. These are modified to allow for the height factor included using a log-log velocity profile for wind data measured at 10 metres. |
| Wind Required | Input wind required for thermal comfort. Reduces Climate data |
| Climate Data | Input wind speed and direction input data. |
| Core Area Factors | Area factors amalgamated |
| Area Factors | Area calculation (for reference only) |

The input climate data used in this study were typical mean year (TMY) data. These consisted of hour by hour monthly averages of the dry bulb temperature, humidity ratio, wind direction, and wind speed. Inside the design tool, north was set as direction 1 while 9 was set as south.

The output from the design tool is the percentage of time that thermal comfort could be achieved (1% being equivalent to 15 minutes/day

RESULTS

Natural ventilation is used in high rise buildings for 3 distinct functions. These are as follows and are in order of increasing air flow requirements:

- The process by which "clean" air (normally outdoor air) is intentionally provided to a space and stale air is removed Openings such as windows, doors and non-powered ventilators provide such intentional openings. The objective of this type of ventilation is better air quality.
- The process whereby the structure or thermal mass of the building is cooled. This is usually done over night or at dawn when the external air is coolest. The objective of this type of ventilation is to reduce the cooling load of the building.
- The process by which air flow on building occupants in hot humid environments improves their thermal comfort. The cooling effect of the airflow on the occupants is due to convection and evaporation of sweat from the skin. The objective of this type of ventilation is thermal comfort.

The figures quoted in later tables are for the last of these functions.

Not surprisingly Auckland appears to have the highest natural ventilation potential compared to either Christchurch or Wellington with Christchurch next and Wellington last. Again not unexpected is the conclusion that thermal comfort in Wellington is not an issue given the high winds and temperate climate. What is interesting is the relative independence of building orientation suggested by these results for all 3 cities. The largest difference for say Auckland is 3.9% (58.5 minutes/day) for a 10 storey building and 2.3% (34.5 minutes/day) for a 30 storey building assuming that the worst and best building orientations were possible. Thus, despite Robertson's call to "orientate" given the temperate nature of New Zealand's climate and the high level of wind orientation, appears not to be required (all things being equal). It should be noted that this is not the case in more tropical humid climates where the need to correctly orientate a building is essential.

Table 2: Potential Thermal Comfort for Varying Building Orientations (Bld. aspect ratio 1)

| Bld. Orientation | Auckland | | Christchurch | | Wellington | |
|---|---|---|---|---|---|---|
| | 10 Storeys | 30 Storeys | 10 Storeys | 30 Storeys | 10 Storeys | 30 Storeys |
| 1 North | 12.5% | 12.9% | 2.5% | 2.9% | 0.0% | 0.0% |
| 2 | 11.9% | 12.0% | 1.7% | 1.7% | 0.0% | 0.0% |
| 3 | 11.3% | 11.4% | 2.3% | 2.3% | 0.0% | 0.0% |
| 4 | 11.4% | 11.4% | 3.6% | 4.5% | 0.0% | 0.3% |
| 5 East | 11.0% | 11.3% | 1.7% | 1.8% | 0.3% | 0.3% |
| 6 | 11.0% | 11.1% | 1.7% | 1.7% | 0.3% | 0.3% |
| 7 | 8.4% | 10.6% | 1.7% | 1.7% | 0.0% | 0.0% |
| 8 | 11.7% | 11.8% | 1.7% | 1.7% | 0.0% | 0.0% |
| 9 South | 12.5% | 12.9% | 2.5% | 2.9% | 0.0% | 0.0% |
| 10 | 11.9% | 12.0% | 1.7% | 1.7% | 0.0% | 0.0% |
| 11 | 11.3% | 11.4% | 2.3% | 2.3% | 0.0% | 0.0% |
| 12 | 11.4% | 11.4% | 3.6% | 4.5% | 0.0% | 0.3% |
| 13 West | 11.0% | 11.3% | 1.7% | 1.8% | 0.3% | 0.3% |
| 14 | 11.0% | 11.1% | 1.7% | 1.7% | 0.3% | 0.3% |
| 15 | 8.4% | 10.6% | 1.7% | 1.7% | 0.0% | 0.0% |
| 16 | 11.7% | 11.8% | 1.7% | 1.7% | 0.0% | 0.0% |

*For a 10 and 30 storey building with an aspect ratio of 1 to 1, core located centrally.

Table 3: Potential Thermal Comfort for Varying Building Orientations (Bld. aspect ratio 3)

| Bld. Orientation | Auckland | | Christchurch | | Wellington | |
|---|---|---|---|---|---|---|
| | 10 Storeys | 30 Storeys | 10 Storeys | 30 Storeys | 10 Storeys | 30 Storeys |
| 1 North | 12.6% | 12.9% | 2.6% | 2.8% | 0.0% | 0.0% |
| 2 | 11.9% | 12.0% | 1.7% | 1.7% | 0.0% | 0.0% |
| 3 | 11.3% | 11.5% | 2.3% | 2.3% | 0.0% | 0.0% |
| 4 | 11.3% | 11.5% | 4.0% | 4.5% | 0.2% | 0.3% |
| 5 East | 11.1% | 11.3% | 1.7% | 1.7% | 0.3% | 0.3% |
| 6 | 10.7% | 11.3% | 1.7% | 1.7% | 0.3% | 0.3% |
| 7 | 9.3% | 10.2% | 1.7% | 1.7% | 0.0% | 0.0% |
| 8 | 11.5% | 12.0% | 1.7% | 1.7% | 0.0% | 0.0% |
| 9 South | 12.6% | 12.9% | 2.6% | 2.8% | 0.0% | 0.0% |
| 10 | 11.9% | 12.0% | 1.7% | 1.7% | 0.0% | 0.0% |
| 11 | 11.3% | 11.5% | 2.3% | 2.3% | 0.0% | 0.0% |
| 12 | 11.3% | 11.5% | 4.0% | 4.5% | 0.2% | 0.3% |
| 13 West | 11.1% | 11.3% | 1.7% | 1.7% | 0.3% | 0.3% |
| 14 | 10.7% | 11.3% | 1.7% | 1.7% | 0.3% | 0.3% |
| 15 | 9.3% | 10.2% | 1.7% | 1.7% | 0.0% | 0.0% |
| 16 | 11.5% | 12.0% | 1.7% | 1.7% | 0.0% | 0.0% |

*For a 10 and 30 storey building with an aspect ratio of 1 to 3, core located centrally.

These findings are not changed even if the building is more "slab" like in dimensions with an aspect ratio of 3 (refer to table 3 above) with only minimal changes of potential thermal comfort from that for a building of aspect ratio 1.

The main lesson from tables 2 and 3 is also that for Wellington and Christchurch designers need to use natural ventilation for indoor air quality issues rather than thermal comfort. And to this end the use of double facades has significant potential.

CONTEMPORARY EXAMPLES

The most contemporary design using natural ventilation is the new Federal Building present under construction in San Francisco. The 18 storey building uses the thermal mass of the floors for night cooling, has a narrow floor plate to allow cross ventilation and a localised double façade shaft on the leeward side of the building. Given the similarity of wind climates such an approach would be suitable for many New Zealand locations.

Figure 3: Contemporary Examples of High Rise Naturally Ventilated Buildings.


The Stattdor building in Düsseldorf is a good example of the use of box double façades. The façade is open along the face of the building and sealed at each floor level. Air flow is then taken in at floor level and expelled at ceiling level. Building occupants can open doors into this area as required.

The liberty tower building in Japan has one floor that is used as a wind floor. This approach then supplements the ventilations of the atrium space inside the building.

Finally while not a strictly a high rise building (and also not strictly naturally vented) the iconic cowlings on top of the building at Jubilee campus Nottingham University suggest potential applications for high rise buildings in New Zealand.

There is presently no similar example in New Zealand other than the Maths and Science Building at Canterbury University (that is 7 storeys high) of a  that is a high rise building using natural ventilation. The above tables suggest that New Zealand has a significant wind climate resource that is not being developed.

## CONCLUSION

Natural ventilation has traditionally been used for low rise residential buildings and its use in high rise and office buildings has been slow internationally and is effectively not realised in New Zealand.

The results in this paper suggest that natural ventilation has definite possibilities for high rise buildings in Auckland (and possibly Christchurch) for thermal comfort. Moreover, all three centres and in particular Wellington have the potential for using natural ventilation for indoor air quality functions. The results also suggest that design criteria used for buildings in warmer climates do not necessarily apply in temperate climates and designers need make wider use of site specific climatic data to ascertain the specific impact and importance of natural ventilation.

But more importantly, the earlier background and the contemporary examples high light that building designers are not considering natural ventilation for high rise buildings. And given the comments at the start of this paper one must question the quality of high rise environments in New Zealand. It appears we are not "returning the can" as Ward warned.

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