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Corrosivity Zones in New Zealand - Definition, Interpretation and Measurement

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Corrosivity Zones in New Zealand - Definition, Interpretation and Measurement

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New Zealand has long fought to protect its structural steelwork from corrosion, perhaps the best-known defence in the battle being the ubiquitous PWD No.2 primer, developed by the public works department largely by trial-and-error. Its effectiveness was undisputed, but its reliance on the (still not fully understood) corrosion inhibiting effect of red lead oxide meant that it was phased out for health reasons.

However, the newer generations of protective coatings were not as tolerant of incomplete surface preparation, and to be fully exploited had to be specified for use in environments whose characteristics were understood, if not totally defined.

In the early 1980s, work on classifying the corrosivity of the New Zealand environment began to take a more ordered approach than the previously scattered efforts[1-6] made by workers interested in one particular site or area. References 1-4 reported measurements of chloride in rainwater, whilst Claridge[5] measured dry deposition rates. Only Shaw and Alcan (NZ) made any cohesive attempt to measure corrosion rates, and this data was not published until 10 years after it had been obtained[6]. The appearance of AS2312[7] in 1980 focussed attention on the issue.

The first big step came in 1982, when a map proposing corrosion zone classification of New Zealand was published[8]. This was derived from measurements of sodium levels in grass, the implication being that since the sodium was probably from sea-salt, an indication of chloride levels would be obtained. This was indeed the case, and the map was later adopted by SANZ as one of the principal elements of MP2312[9]. Before this was released, studies of the New Zealand environmental corrosivity continued, using CLIMAT galvanic test units[10]. These were exposed along with steel coupons, to record actual corrosion rates as weight loss measurements, but were limited in their coverage.

In 1987, BRANZ began a study of atmospheric corrosivity at approximately 180 sites around New Zealand. Four panels each of mild steel, galvanised steel, and aluminium were exposed on racks, with the rack minders being asked to return one panel of each metal at 1, 2, 5, and 10 years after exposure. Results have been reported[11-13] after 1, 2 and 6 years, confirming the original assumptions made in the production of the salt map in 1982. However, the results obtained for aluminium panels have been erratic, confirming that for this metal exposed outdoors, microclimatic factors are more important than gross atmospheric corrosivity. This suggested that a new direction in the research was necessary. In the meantime, however, the standards into which the work was feeding results had been keeping pace, and had become more useful.

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Similar talk given to Auckland Division of Australasian Corrosion Association, May 16, 1996.

Corrosion standards in Australasia.

Much of this material will be covered elsewhere (see W. Mandeno's paper), so should only be touched on here. MP2312/ AS2312-84 covered most of Australia and New Zealand in limited detail, because the corrosion zones/categories proposed therein were estimated from atmospheric factors such as rainfall and chloride deposition levels. As such, their usefulness in describing an environment was relative only, to other environments described.

The International Standards Organisation (ISO) became active in the area of corrosivity classification in the mid-1980s, driven by committee TC/156 WG/4. Their first act was to establish a global experiment, known as ISOCORRAG, with some 30 countries taking part. This involved the atmospheric exposure of various samples, identical in each country, to establish a global ranking and also to gain an understanding of the various factors influencing corrosion rates.

Analysis of the results led to the publication of a range of atmospheric corrosivity classification standards, dealing with measurement of pollution, measurement of corrosion rates, and classification of environments. A method of predicting corrosion rates using measured atmospheric parameters was also introduced.

ISO 9225:1992[14] introduced a new standard method for determining chloride deposition rates, using a wet candle. Using the results provided by this, and combining them with humidity (approximating Time-of-Wetness, TOW), ISO 9223:1992[15] provided a method of predicting the corrosion rate for that location, and a classification scheme for assessing the severity of the derived rate. Atmospheres are ranked between C1 (benign, such as a desert) and C5 (extremely severe, such as in the marine splash zone).

New Zealand is fortunate to have both measured TOW, and chloride deposition rates, for sites where the flat panel corrosion rate had also been measured. This enabled workers to check the validity of the ISO prediction methods using real data, leading to the conclusion that they did not work reliably for all sites. In severe marine areas, the predicited corrosion rate was often one category too high compared to what was actually measured with exposed metal coupons. The problem is believed to be due to deficiencies in the TOW definition and measurement; in New Zealand the relative humidity on a dry day is often higher that it is in some countries where rain would fall. That is, in New Zealand the metal coupons are expected to be wet at high humidities, but are actually not.

The categories introduced in ISO 9223 were too broad to cover New Zealand and Australia adequately, and in the revised version of AS/NZS 2312[16], released in 1994, a finer classification scale is used. The most important difference between this and earlier versions of the standard was that the corrosivity zones were now defined by corrosion rates, which could be established independently in each country, rather than by inference from other measurements. The zone descriptions have been realigned to remove needless duplication, such as the old arid/mild deliniation (replaced with a single MODERATE zone), and split the single marine zone in to MARINE and SEVERE MARINE. TROPICAL and INDUSTRIAL zones can not just be defined by corrosion rate, however, as factors such as humidity, temperature, and pollution may not show a similar effect on bare steel corrosion rates as they do on coating durability. Care is required when assessing these zones. In New Zealand, there are few true industrial zones, those which do exist being extremely localised to the obvious source of pollution. However, the geothermal region centered on Rotorua is usually classified as industrial, and extreme care is needed when assessing steel performance in this zone. Background corrosion rates are in the mild/moderate categories, but locations near fumaroles, or plant which draws on geothermal energy will usually be in extremely aggressive environments, extending into ISO C4 or above. The effect of the recent Mt Ruapehu ash eruptions on corrosion rates of roofs, gutters, bridges, and cars is yet to be felt, but the affected regions have probably moved from mild to industrial classifications.

A list of first year mild steel coupon corrosion rates is given in Table 1, covering most of the inhabited parts of the country. A conversion between μm/yr and $g/m^2/yr$ is shown for each relevant AS/NZS 2312 environment, below.

MILD	0 - 10 μm/yr (0 - 80 $g/m^2/yr$)
MODERATE	10 - 25 μm/yr (80 - 200 $g/m^2/yr$)
MARINE	25 - 50 μm/yr (200 -400 $g/m^2/yr$)
SEVERE MARINE	> 50 μm/yr (> 400 $g/m^2/yr$)
INDUSTRIAL	> 25 μm/yr (> 200 $g/m^2/yr$)

As can be seen, much of the country falls in to the moderate zone, including most residential areas. However, many of the larger buildings found in the main centres' CBDs will be in a marine zone. Care must therefore be taken in obtaining the correct environmental information before even beginning to design such a building.

Microclimates

All of the standards mentioned above have dealt with measurements of gross atmospheric corrosivity; in other words, items exposed fully to the weather. However, reality is that most building products are exposed in a semi-sheltered manner across part of their surface. The areas which are not fully rainwashed are referred to as influenced by microclimates. The definition of the size of a microclimate is blurry, depending on application. For instance, a city street can be thought of as a microclimate, and so can the unwashed top part of a garage door. In the present paper, the latter definition is used.

The beneficial effects of rainwashing are not always fully recognised. Basically, the problem is that salt and dirt deposited on a metal surface and not washed off will accelerate corrosion. This is true for any common building metal, including stainless steel (as discovered by WRC on the Michael Fowler Centre), painted or not. Corrosion is accelerated because sea-salt absorbs water from the air when the relative humidity exceeds about 75%, creating a very concentrated salt solution on the surface. Chloride ions are particularly aggressive towards steel, zinc and aluminium, and will rapidly cause corrosion. Protective coatings delay this by various methods, and to varying degrees of success.

Thus, a method is needed of predicting the aggressiveness of a microclimate, quickly and reliably. The most sensible way is to measure the parameters which affect corrosion, and use them to predict the corrosiveness, *cf.* ISO 9223[15]. However, it is understood in both ISO 9223 and AS/NZS 2312[16] that this is not currently possible, as further work is needed to define the formulae/algorithms needed, and both standards warn about the effects of microclimates.

BRANZ is currently looking at the problem in some detail, as is CSIRO[17]. BRANZ research is focussed on measuring corrosion rates (with flat panels) in microclimatically-influenced areas, as well as measuring the chloride deposition rates and humidities. From this it should be possible to derive a predictive formula for corrosion rates of steel. The important point to note is that the steel panels used are identical to those used in the nationwide atmospheric corrosion survey, meaning that it is possible relate gross measurements directly to microclimatically-influenced ones. Until the formula(e) become available, however, comparisons will have to be empirical, via expert interpretation. A further caveat, and an extremely important one, is that it is not possible to use corrosion rates for one metal to predict corrosion rates for another. For example, steel corrosion rate measurements can not be used as a predictor of galvanising performance, because of the difference in corrosion mechanism between the two metals. Steel corrodes at the interface between the metal, and the corrosion product (ie, under the rust), whereas zinc (and hence galvanising) corrodes at the interface between the corrosion product and the atmosphere. Thus, zinc surfaces react to changes in atmospheric conditions quicker than do steel ones.

The subfloor space of houses with suspended (pile) floors is a classic microclimate. The space must be ventilated to keep the humidity low, and the timbers dry, to prevent corrosion of steel fasteners and fungal growth on, and rot of, timbers. However, at the same time, the ventilation arrangements must exclude salt as much as possible, for houses near the coast. These two conflicting requirements, combined with the building code requirement that subfloor fasteners be durable for 50 years, led to the establishment of a dedicated research project, looking at salt deposition in subfloor spaces as a function of ventilation type and area. An enclosure contining eight model subfloors has been built in a severe marine environment on the south coast of Wellington. Each model subfloor has different ventilation arrangements, ranging from totally closed to totally open. In each enclosure, ISO chloride wicks measure salt levels at three places in the enclosure, and humidity levels are monitored by moisture content measurements of a "calibrated" piece of 100x50mm Pinus radiata. The open enclosure is also fully instrumented with humidity and temperature sensors. Each enclosure also has a set of flat panel steel and galvanised steel coupons, to tie the results back to the earlier corrosion survey. Zincalume coupons are also included, as the chance to obtain further exposure information on this new (to New Zealand) material had to be taken.

The information obtained from this experiment has already led to some changes in thinking about subfloor fastener durability, especially for pole houses, and houses with open subfloors. The implications for any steel structure are also plain; any design must identify areas of the structure which may be microclimatically influenced, especially during constuction, and eliminate them, or impose a maintenance schedule.

Concluding comments

The corrosivity of the New Zealand environment has been assessed, and can be classified according to ISO 9223:1992, or AS/NZS 2312:1994. For the purposes of material and coatings selection, the latter standard, with its finer classification scale, is more suitable for use in New Zealand.

Much of urban New Zealand is in the Moderate zone, but care must be taken in main centres, as waterfront buildings may well be in a Marine area.

The geothermal area bounded by Te Puke, Kawerau, Ohakune, and Waiouru consists largely of moderate areas, but isolated "hot spots" can cause steel corrosion rates of up to 5000 $g/m^2/yr$ (625 µm/yr). The local authorites in these regions should be consulted before planning and building work, as they have reasonable information on localised geothermal activity.

Extreme caution should be taken in design work to avoid details which expose metallic items to salt and dirt but allow no natural rainwashing. These microclimatic situations can cause rapid corrosion of exposed steel, often in critical areas, failure often only being noticed after a structure collapses.

Table 1

First year mild steel corrosion rates (g/m^2)

NORTHLAND	
Kaitaia	188
Kerikeri Aero	203
Waiotemarama	179
Waipoua Forest	158
Dargaville	212
Whangarei Aero	234
Marsden Point	285
Leigh	304
Warkworth	191
Woodhill Forest	191
Muriwai	440

AUCKLAND	
Whenuapai	248
Takapuna	142
Albert Park	152
Auckland City	259
Parnell	165
Auckland Harbour	390
Owairaka	152
Penrose	229
Ellerslie	190
Auckland Aero	298
Ardmore	209
South Head	327

WAIKATO	
Pukekohe	192
Glenbrook	155
Maioro Forest	181
Hunua	180
Maramarua Forest	150
Te Kauwhata	217
Thames	136
Paeroa	160
Te Aroha	115
Ruakura	130
Hamilton Aero	142
Cambridge	131

TAUPO AND KING COUNTRY	
Mohakatino	267
Arapuni	104
Waikeria	128
Te Kuiti	124
Wairere	163
Pureora Forest	107
Taumarunui	105
Kinleith	308
Atiamuri	74
Taupo	120
Wairakei	155
Taupo Aero	104
Waimihia Forest	91
Turangi	107
Chateau, Mt Ruapehu	96
Ohaaki DSIR	391
Ohaaki Power Station	109

TARANAKI	
New Plymouth	247
Stratford	188
Kapuni	230
Patea	218

MANAWATU AND WANGANUI	
Ohakune	85
Waiouru	155
Ahu Ahu	112
Taihape	71
Wanganui Aero	352
Flockhouse	208
Kairanga	203
Palmerston North Aero	168
Waitarere Forest	224
Levin	194

BAY OF PLENTY	
Whangapoua Forest	158
Tairua Forest	170
Waihi	163
Katikati	146
Tauranga Aero	195
Te Puke	154
Rotoehu Forest	155
Edgecumbe	146
Whakatane Aero	196
Kawerau	294
Kaingaroa	109
Murupara	96

HAWKES BAY	
Manutuke	141
Gisborne Aero	194
Onepoto	90
Wharerata Forest	175
Esk Forest	86
Napier Aero	153
Havelock North	101
Taradale	82
Mohaka Forest	114
Frasertown	153
Waipukurau	119

ROTORUA	
Tikitere	243
Rotorua Aero	207
Lynmore	153
Koutu	117
Ngapuna	2293
Springfield	218
Ohinemutu	222
Lake Rotoatamaheke	4800
Waiotapu Forest	111

WAIRARAPA	
Dannevirke	114
Castlepoint	232
Tauherenikau	124
Mt Bruce	128
Waingawa	142

WELLINGTON	
Avalon	164
Judgeford	153
Kelburn	128
Thorndon	173
Thorndon (sheltered)	194
Somes Island	243
Gracefield	167
Wainuiomata	165
Wellington Aero	268
Kaitoke	146
Wallaceville	145
Paraparaumu Aero	240

MARLBOROUGH	
Riwaka	95
Tapawera	97
Appleby	104
Nelson Aero	162
Rai Valley	105
Brancott Valley	58
Lake Grassmere	270
Lake Rotoroa	34

WEST COAST	
Westport Aero	375
Hokitika Aero	235
Reefton	253
Greymouth	511
Otira	102
Springs Junction	66
Harihari	150
Franz Josef	118

CANTERBURY	
Hanmer Forest	37
Kaikoura	223
Arthurs Pass	49
Culverden	76
Cheviot	108
Craigieburn Forest	25
Highbank	76
Ashburton	138
Eyrewell Forest	74
Christchurch Aero	206
Christchurch	152
Bromley	207
Lincoln	175

SOUTHLAND	
The Hermitage	30
Kelman Hut	23
Lake Tekapo	18
Fairlie	53
Twizel	22
Geraldine	75
Timaru Aero	144
Waimate	74
Kurow	55
Omarama	17
Ranfurly	34
Palmerston	90
Taiaroa Head	239
Dunedin Aero	127
Musselburgh	243
Alexandra	34
Tapanui	73
Winton	148
Gore	121
Invercargill Aero	253
Tiwai Point	341
Finegand	145

References

1. Blakemore, L.C. 1953. The chloride content of rainwater collected in the Wellington provence. *New Zealand journal of science and technology 35:*193-197.
2. Blakemore, L.C. 1973. Element accessions in rainwater at Taita, New Zealand, 1963-1971. *New Zealand Soil Bureau scientific report 17.* Wellington, DSIR.
3. Miller, R.B. 1961. The chemical composition of rainwater at Taita, New Zealand, 1956-1958. *New Zealand journal of science 4:* 844-853.
4. Claridge, G.G.C. 1975. Element accessions in rainwater, Catchment 4, Taita Experimental Station, 1969-1974. *New Zealand Soil Bureau scientific report 24.* Wellington, DSIR.
5. Claridge, G.G.C. 1975. Studies in element balances in a small catchment at Taita, New Zealand. Proceedings of a symposium of research in representative and experimental basins, Wellington 1970. *International Association for Scientific Hydrology publication no. 96:*523-540. [Also available as *Publication no. 491*, Soil Bureau, DSIR Wellington]

6 Duncan, J.R. 1984. Atmospheric corrosion in New Zealand. *Corrosion Australasia*; October 1994. Australasian Corrosion Association, 1984.

7. Standards Association of Australia. 1980. *Guide to the protection of iron and steel against exterior atmospheric corrosion.* AS2312:1980.
8. Duncan, J.R., Whitney, R.S. 1982. Suggested zones of steel corrosion hazard in New Zealand atmospheres. *TRANS., Vol. 9 No. 3/EM/Ch, December 1982.* Pp 65-75.
9. Standards New Zealand. 1987. MP2312: Commentary on AS2312:1984 Guide to the protection of Iron and steelwork against exterior atmospheric corrosion. SANZ, Wellington.
10. Cordner, R.J., et al, 1987. Atmospheric chloride deposition at Judgeford, New Zealand. *New Zealand Journal of Technology, Vol 3.* Pp 219-225.
11. Cordner, R.J. 1990. Atmospheric corrosion survey of New Zealand. *BRANZ. Corros. J.*, Vol 25, No2. Pp 115-118.
12. Duncan, J.R., & Cordner, R.J., 1991. Atmospheric corrosion rates over two years' exposure at 156 sites in New Zealand. *IPENZ Transactions Vol 18 No.1/GEN.* pp 1-13
13. Kane, C.D., 1996. Atmospheric corrosion survey of New Zealand - 6 year exposure results. *IPENZ Transactions, in press.*
14. International Organisation for Standardisation. 1992. Corrosion of metals and alloys - Corrosivity of atmospheres - Measurement of pollution. *ISO 9225:1992(E).* ISO, Geneva.
15. International Organisation for Standardisation. 1992. Corrosion of metals and alloys - Corrosivity of atmospheres - Classification. *ISO 9223:1992(E).* ISO, Geneva.
16. Standards Australia/Standards New Zealand. 1994. Guide to the protection of iron and steel against exterior atmospheric corrosion. *AS/NZS 2312:1994.* SAA/SNZ, Homebush/Wellington.

17 Norberg, P., King, G.A, O'Brien, D.J. 1996. Corrosivity and microclimate measurements in open and sheltered marine environments. *Durability of Building Materials and Components 7 (Volume 1),* Conference proceedings. C.Sjostrom (Ed.) E & FN Spon, London.

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