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LIFE CYCLE COSTS OF CLADDINGS

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LIFE CYCLE COSTS OF CLADDINGS

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KEYWORDS

Life cycle costs; claddings; costings; maintenance; environment.

ABSTRACT

Life cycle cost analysis is a technique which allows for consistent comparisons of the net costs of buildings and components throughout their life. It enables valid comparisons between materials with different initial and ongoing costs and different life spans.

This report examines the life cycle costs of a variety of common roof and wall cladding systems used in low-rise residential and commercial buildings in New Zealand. Up to three maintenance options and two environment conditions are described and analysed for each system.

LIFE CYCLE COSTS OF CLADDINGS

Contents : **Page No.**

TABLES

Contents : **Page No.**

FIGURES

1.0 INTRODUCTION

This study sets out cost data and maintenance options for roof and wall claddings commonly used on dwellings in New Zealand. This data has been compiled to assist those involved in selecting cladding systems for dwellings and commercial or institutional low-rise buildings. The choice of material has ongoing cost implications in terms of maintenance and, eventually, the replacement of the cladding system. A system chosen on the basis of lowest initial cost may not necessarily be the cheapest solution when all costs throughout the life of the cladding are included. For this reason life cycle cost (LCC) analysis is used to compare cladding systems.

LCC analysis attempts to allow cost comparisons to be made on a consistent basis. It involves the appropriate discounting of payments at various times in the future so that valid comparisons can be made of alternatives which have different initial costs, different maintenance costs and different life spans. Further details of the technique are given in the Appendix and in references (1), (2) and (3).

2.0 SCOPE

The data collected in this study includes:

- initial costs
- maintenance costs
- maintenance options
- life of materials.

This, together with the discount rate, is all the data that is required to carry out a life cycle cost analysis. The results of the analysis are shown in tabular and graphical format in this report.

Costs included are initial and maintenance costs only. Salvage values and disposal costs have been ignored, mainly because the cost impact is very small, as discussed in the following section. Any environmental costs associated with embodied energy and CO_2 emissions are assumed to be represented in the market price of energy and included in the initial cost of the material. The different thermal performance characteristics of claddings has not been specifically included although there is some discussion of this effect in Section 3.

The analysis was carried out in a spreadsheet and persons with minimal knowledge of spreadsheets would be able to insert their own assumptions on costs and durations and compare the results with the options used in this report. Menu-driven life cycle costing packages are available, and two of these packages are reviewed.

3.0 RESULTS

The maintenance options and periods, and material lives, for moderate environments are shown in Tables 1 and 2. They were derived in discussion with scientists in the BRANZ Durability Group and are estimates only. Material and maintenance costs, and life cycle costs, are given in Tables 3 and 4 and are shown graphically in Figures 1 to 6. The analysis was carried out for two types of nominal environment, namely a moderate environment and a marine/severe environment. A definition of environmental conditions is included in the Appendix. The maintenance options for the severe environment are not shown, but are identical to those in Tables 1 and 2 except that the maintenance return periods and the material life have been reduced by the factors given in Table 6.

The life cycle cost has been expressed in the form of an equivalent annual cost. It consists of the initial cost, expressed in terms of annual payments (ie similar to mortgage payments), plus the maintenance costs converted into annual costs, as explained in the Appendix. The reason for using annual costs rather than other alternatives, such as present value, is that the former automatically adjusts for the different life spans of the materials. If the present value measure was used then longer-life materials would have a bias toward higher present values, as maintenance is counted over a longer period than for short-life materials. The annual cost method also automatically allows for multiple replacements of the cladding system over the life of the building, since the initial cladding cost is spread over the total cladding life.

The discount rate allows for the time value of money, in which expenditure delayed until the future is worth less than expenditure required now. A base case real discount rate of 8% has been used, as discussed in the Appendix. Figures 7 to 9 show some results for other rates.

Two of the earlier analyses were re-run using different maintenance options, to check the sensitivity of the annual costs to maintenance regimes. They were:

- Roof cladding annual costs versus environmental conditions using maintenance option 2 instead of maintenance option 1 (see Figure 10).

- Roof cladding annual costs versus discount rate using maintenance option 2 instead of maintenance option 1 (see Figure 11).

Initial costs of materials are from the Rawlinson cost handbook (4), which was also used to derive most of the painting costs shown in Table 5. Note that the costs include materials required to immediately support the cladding material. For roofs this includes purlins, battens, building paper and plywood sarking, as required. For heavy roofs such as concrete tiles allowance has been made for additional structural costs of the trusses, lintels and wall bracing. For wall claddings the only additional costs are for backing material to support stucco. Any additional foundation costs to support heavy claddings such as brick or concrete block have not been included.

4.0 DISCUSSION

4.1 Cost ranking of materials

The cheaper roof claddings, in terms of life cycle costs, are galvanised steel roofs and concrete tile roofs. For wall claddings the lowest life cycle costs are for aluminium and fibre-cement weatherboard, plywood sheet cladding and concrete block. Timber weatherboards and synthetic rubber sheet are expensive, mainly due to their high initial cost. Initial cost is an important influence on life cycle costs, and there is an approximate linear relationship between life cycle cost and initial cost, as shown in Figures 1 and 4. However, the cheapest materials do not always have the lowest life cycle cost. For example, concrete tiles are significantly more expensive than galvanised corrugated steel (painted after installation) but the life cycle cost of the former is some 19% lower with maintenance option 1, the most common maintenance option. Note, however, in maintenance option 2 where the galvanised steel roof is left unpainted for the first 15 years the steel option is cheaper than concrete tiles (see Figure 10).

In many situations the choice of material by a new homeowner will be based on factors other than cost. While initial and maintenance costs will have some bearing, the main consideration will be matching the material to the style and quality image of a house. In these cases life cycle costing is still useful as it quantifies the cost implications of the aesthetic aspects of the design.

In other cases the owner will have in mind the resale value of the property and may choose the material on that basis. The resale price will include the buyer's perceptions of the maintenance requirements and durability of claddings, and these perceptions may well differ from reality. For example, stucco may be considered to be maintenance free and hence the buyer may pay more than he/she should, or alternatively fibre-cement may be considered a non-durable material with a higher maintenance requirement than is actually required and hence the resale price is lower than would otherwise be the case. Generally, buyers and sellers lack full information on these matters and may make sub-optimal decisions, favouring low-maintenance materials which may have higher life cycle costs, but which the owner believes will have a higher resale value. In this case the owner is acting in his/her best interests by specifying low maintenance materials.

4.2 Environmental conditions

The effects of the environmental conditions are shown in Figures 3 and 6 for option 1 maintenance. For roof cladding, the largest increases in annual life cycle costs, moving from a moderate to severe environment, are for butyl rubber sheet and glass-reinforced plastic (GRP) products and metal tiles, closely followed by corrugated galvanised steel claddings. The increase in life cycle costs is between 17 and 19% in these materials. For wall claddings the largest increases are PVC weatherboard claddings at around 12%. Concrete materials generally have a negligible increase in costs, reflecting the inherent stability of the base material under marine or severe environmental conditions. These results closely reflect the environmental factors used (see next paragraph) with butyl, GRP and steel all having the smallest factor at 0.7. However, there will be situations where a lower factor could be applied for one or other of the materials, and this would increase the life cycle costs.

The analysis assumes that the severe environmental impact on a material is condensed into one factor, which has been applied to the moderate environment material life and maintenance return periods. This factor, between 0 and 1, is separate for each material, and it simplifies the calculation of life cycle costs (see Table 6). In effect, the assumption is that the impact of a severe environment can be allowed for by reducing the moderate environment material life and the period between maintenance, keeping other variables such as type and costs of maintenance unchanged.

This is obviously a simplification since an alternative, and possibly more likely, scenario is that in a severe environment maintenance would involve different initial and replacement coatings and procedures, and be to a higher quality than in the moderate environment. These alternative scenarios could be readily analysed in the current framework but would involve collecting almost as much information again on durability and costs for the alternative initial surface finishes and maintenance regimes for severe environments, and would not necessarily apply to all severe environments.

An extension of the work to include collection of this data is discussed in the conclusions. For unusually severe environments it is suggested that the appropriate cost data be obtained for each particular case and the model run for two or three tailor-made protective systems and maintenance regimes.

It was considered that the increase in life cycle costs moving from a moderate to a severe environment, might be affected by the maintenance regime used. To check this the analysis was repeated for maintenance option 2 instead of maintenance option 1 used above. Only roof claddings were analysed to see if a changed maintenance regime affected changes in life cycle costs. The results in Figure 10 can be compared with those in Figure 3 from the original analysis. The increase in life cycle costs was similar to option 1, although the increases for butyl products were slightly lower, at around 14%.

4.3 Discount rate

In Figures 7 and 8 the discount rate, R, has been varied for roof cladding materials. The largest change in annual costs occurs in concrete tiles, with a 61% reduction in costs, going from a discount rate of 12% to 4%. The lowest change is for metal tiles and butyl rubber sheet products, which show a 45% change in annual costs. These examples are for maintenance option 1 and demonstrate the effect of the discount rate on future maintenance costs, particularly for the more durable materials such as concrete. Below R=6.5%, concrete tiles are the cheapest roof cladding but higher discount rates penalise their long life and low maintenance characteristics, as the future maintenance cost savings, compared to other materials, are heavily discounted. For wall claddings (see Figure 9) changing the discount rate does not greatly affect the relative order of life cycle costs of materials except for concrete block.

Another maintenance regime (option 2) for roof claddings was also analysed only to see if it affected changes in life cycle costs (see Figure 11) and to compare it to Figure 7. The pattern of changes in life cycle costs as the discount rate changed was similar to before, with no outstanding changes.

A base discount rate of 8% was chosen, as described in the Appendix. This is judged to be a reasonable estimate of the long-term real interest rate for homeowners over the next 10 years. Hence the upper and lower margins of the range of discount rates shown in the figures are unlikely to be reached in practice.

4.4 Maintenance options

Up to three maintenance options were analysed for each material. Those shown are considered to be the most likely regimes but in practice a wide variety of maintenance schedules and coatings are possible and it was not possible to analyse them all. In most cases the first option is the most common for dwellings but is not always the cheapest (see Tables 1 and 2 for the options and Tables 3 and 4 for the life cycle costs). For example, for metal roofs the lowest cost option is the low or nil maintenance option (option 3 in Table 1). The life of the material is drastically reduced but it is cheaper to replace it after a limited life than to carry out regular maintenance. It should be noted that the analysis does not allow for costs associated with the aesthetic appearance of a cladding. Most owners do not wish to live in a dwelling with an unmaintained appearance. Also, if the owner wished to sell the dwelling it is possible that the sale price penalty for an unmaintained appearance could outweigh the cost savings of neglected aesthetic maintenance. Therefore, in practice, owners have good reasons to maintain the appearance more often than the analysis might suggest.

Another reason for regular maintenance is that it enables early detection of potentially expensive unexpected material failures or damage. For example, a penetration through exterior cladding could cause considerable damage to the framing and linings before it became obvious to the homeowner. It is likely that the cost of repair would far outweigh any savings that may have been made in deferring maintenance, but these particular benefits have not been included in the analysis due to the difficulty of quantifying them.

Other maintenance options can be readily run through the LCC model and the results compared to the standard cases of this report. The aim of the model is to achieve a better understanding of the life cycle costs of materials so that designers, builders and owners are better informed of the cost implications of their decisions.

4.5 Salvage and disposal costs

These costs have been ignored in the analysis, partly because of lack of data but mainly because their effect on life cycle costs is likely to be small. As an example, consider demolition and disposal costs for concrete block walls. Data from Rawlinsons (4) suggests that the demolition and disposal cost for reinforced block wall is around $6 per sq metre of floor area, which converts to around $10 per sq metre of net wall area. This expenditure, say 50 years in the future, translates to an equivalent annual cost of around $0.02 per sq metre of wall area, which under current demolition and disposal regulations is negligible.

4.6 Variability

The analysis has used or assumed average values for durability of materials, exposure conditions and quality of workmanship. However there will, in practice, be some variation in:

- durability of similar materials from different manufacturers and between different batches from the same manufacturer;
- quality of initial installation and the actual construction regime used;
- quality of maintenance;
- exposure conditions, which will be spread over a range of conditions rather than the two states analysed.

These possible causes of variation have not been analysed but life cycle costs could be significantly affected to a greater or lesser extent, depending on the material. For example, materials which are dependent on well-controlled maintenance and/or installation procedure, such as corrugated steel roofs or stucco walls, could have higher than expected maintenance costs and shorter lives if the work is not carried out correctly. In contrast, a material such as fibre-cement may be less sensitive in life cycle cost terms to lapses in the standard of maintenance.

4.7 Thermal performance effects

The thermal performance of the various claddings will all differ and hence they will have different space heating costs, which could be included in any assessment of life cycle costs. This was not done in this analysis mainly because the thermal performance of most of the materials is similar. The main exception is EIFS walls which have an "in-built" insulating effect from the polystyrene layer. The approximate thermal resistance difference between EIFS, with 40mmm expanded polystyrene, and uninsulated walls of other claddings is R1.1, which approximately equals 50mm of fibreglass segments at $5/sqm. Hence, to carry out the life cycle cost comparision on the same basis, $5/sqm should be subtracted from the initial cost of the EIFS. This changes its life cycle cost for maintenance option 1 from $7.15/sqm to $6.73/sqm, a small change which does not affect its relative ranking (see Figure 4).

4.8 Software packages

Two life cycle cost analysis computer packages were reviewed:

- NIST Building Life Cycle Cost program Version 4.0. (5).
- FINFEAS2 A program for modelling the life cycle costs of a building project. CSIRO. (6).

Both of these programs are menu driven and assess the life cycle costs of buildings and their components. They run on IBM AT compatible personal computers.

The first of these programs runs in DOS and consists of the main program plus a simplified program called DISCOUNT. The main NIST package is especially useful for handling energy costs as well as other operating and maintenance costs. Non-periodic costs can be included, as can periodic uniform and escalating costs. It is suitable for carrying out the type of analysis covered in this report. All data, including maintenance costs and timings, needs to be entered for each run. Its main disadvantage is that since it has an emphasis on energy costs it is not possible to by-pass the energy input menu. When used for non-energy related analysis the user needs to insert several zeros in the energy use panel in order to proceed to the next stage. However, apart from this slight difficulty, it provides all the options required, including a variety of outputs (annual costs, present values, internal rate of return, payback period, savings to investment ratio), comparison of alternatives, ability to save and recall datasets, facility to handle tax and depreciation rates on operating and plant costs, etc.

The simplified program DISCOUNT computes discount factors and related present values, future values, periodic payment values of cash flows and the present value of periodic payments which increase at a given rates over time. It is useful for quick calculations of single one-off payments or periodic payments but is unable to handle a combination of payments to give present values and would generally be unable to carry out the type of analysis done on claddings in one stage.

The FINFEAS2 program runs in Lotus 1-2-3 and is oriented toward assessing the financial feasibility of large building projects. It allows for financing costs during construction and includes provision for rental income by floor, and vacancy rates, as well as allowing for all approvals, design, project management, construction, fitout, maintenance, operating, refurbishment and replacement costs. Outputs include graphs of cashflow, rentals, construction costs, net present value, internal rates of return, etc. The package is not suited to component life cycle cost analysis, as described in this report, due to the range and complexity of the required inputs which are difficult to by-pass for simple component analyses.

It is suggested that if designers, specifiers or manufacturers require an easy-to-use general LCC package then, of the two packages reviewed here, the NIST software be used. It is suitable for a range of LCC-type analyses and is sufficiently versatile to be put to a variety of uses. However, if users only require an occasional analysis and have basic spreadsheet literacy then the best approach may be to use the standard financial functions offered in spreadsheets and carry out one-off analysis. The analysis for this study report was carried out using the Microsoft Excel spreadsheet package, rather than any of the packages described above. Excel was used because it enabled all materials to be analysed similtaneously and integrated into tables and figures. With the NIST package it would have been necessary to analyse the materials individually and then transfer the results to a graphical package.

Other packages are available overseas but have not been reviewed. Some of these may be more useful in New Zealand than the two described above.

5.0 CONCLUSIONS

The life cycle costs of a range of common cladding materials, under moderate and severe environmental conditions, and for various maintenance options, are assessed in this study.

The initial cost of a cladding material is a major variable in LCC analysis. Generally, but not always, cheaper materials have lower life cycle costs. Often other considerations apart from cost (such as aesthetics) will govern the choice of material and maintenance regime, and LCC analysis quantifies the cost implications of those decisions.

Neither of the computer packages assessed were found to be tailored for component LCC analysis. However, of the two that were assessed, the NIST package is the easier to use, with minimum difficulty in analysing low-rise buildings and their components.

It is recommended that future work be in four main areas:

- Reassessment of the maintenance regimes for severe environments using protective systems particularly formulated for the situation. The results should then be compared to the simplified method used in this study in which the only change from moderate environment maintenance was to shorten down the maintenance period.

- Extending the range of claddings to include those used on low-rise commercial, industrial, and institutional buildings.

- Documenting and tidying up the spreadsheet model for use by designers and specifiers. Investigating, and if feasible, producing a simple menu-driven overlay for the model.

- Investigating the feasibility of tying-in economic life cycle costing with environmental life cycle analysis. Environmental LCA and its analysis methodology is still being developed and much of the local data is still being gathered. To link the two a common unit will be required. Future work could investigate the feasibility of better defining the costs of environmental effects and linking these into a combined building life cycle cost analysis.

6.0 ACKNOWLEDGMENT

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TABLE 1 ROOFING MAINTENANCE OPTIONS

MODERATE ENVIRONMENT

	OPTIONS	TYPE OF WORK, MAINTENANCE INTERVAL AND LIFE SPAN
CONCRETE TILES AND SHINGLES	OPT1	Repair pointing/ waterblast every 20 years, replace at 60 years
	OPT2	Repair pointing/ standard acrylic paint 2 coats every 8 years, replace at 75 years
	OPT3	Repair pointing/ high-build acrylic paint 3 coats every 15 years, replace at 90 years
GALV. CORRUG. STEEL 0.40mm & 0.55mm	OPT1	Paint on installation, repaint every 7 years. Blast clean at 35 years, repaint. Replace at 50 years
	OPT2	Install unpainted, paint after 15 years. Repaint every 7 years. Replace at 40 years
	OPT3	Install unpainted, hose down every year. Do not paint. Replace at 20 years
PRE-PAINTED GALV. STEEL 0.40mm & 0.55m	OPT1	Repaint after 15 years, every 7 years thereafter. Blast clean at 40 years, continue repainting at 7 years. Replace at 50 years
	OPT2	Blast clean/ repaint after 15 years. Repaint at 10 year intervals using high build acrylic. Replace at 50 years
	OPT3	Hose down every year. Do not repaint. Replace after 35 years.
ALUMINIUM, CORRUGATED	OPT1	Paint on installation, repaint every 7 years. Blast clean at 40 years, repaint. Replace at 60 years
	OPT2	Install unpainted, paint after 20 years. Repaint every 7 years. Replace at 50 years
	OPT3	Install unpainted. Do not paint. Replace at 40 years
METAL TILES, AGGREGATE COATED	OPT1	Hose down regularly, waterblast/repaint/rechip after 15 years. Continue repainting at 7-year intervals. Replace at 50 years
	OPT2	Hose down regularly,waterblast/repaint/rechip after 25 years.Replace rusted tiles as necessary. Repaint every 7 years. Replace at 50 yrs
	OPT3	Wash down yearly. Replace after 35 years
METAL TILES, FACTORY COATED	OPT1	Hose down regularly, repaint after 15 years. Continue repainting at 7 year intervals. Replace at 50 years
	OPT2	Hose down regularly, repaint after 25 years. Replace/repair rusted tiles as necessary. Repaint every 7 years. Replace at 50 years
	OPT3	Wash down yearly. Replace after 35 years
TIMBER SHINGLES, CEDAR	OPT1	Replace cracked shingles after 5 years, then every 10 years. Replace after 40 years
	OPT2	Replace cracked shingles after 10 years only, no other maintenance. Replace after 25 years
	OPT3	Replace and paint shingles after 10 years then every 10 years. Replace roof after 50 years
FIBRE-CEMENT SHINGLES	OPT1	Replace cracked shingles/ waterblast every 15 years, replace at 50 years
	OPT2	Replace cracked shingles/ standard acrylic paint 2 coats every 8 years, replace at 55 years
	OPT3	Replace cracked shingles/ high build acrylic paint 3 coats every 15 years, replace at 70 years
GLASS REINFORCED POLYESTER SHINGLE	OPT1	Replace after 20 years, no maintenance, battens OK for another 20 yrs. (aesthetics may dictate replacement at 10 years)
	OPT2	Replace cracked shingles/ standard acrylic paint 2 coats every 8 years, replace at 40 years
SLATE, BUTYL RUBBER	OPT1	Wash down periodically with warm soapy water, replace at 20 years, ply sarking OK for another 20 yrs
	OPT2	Paint with light coloured reflective (aluminium) paint every 7 years, replace at 35 years
FIBRE-CEMENT, CORRUGATED	OPT1	Water blast at 15-years intervals, replace at 40 years
	OPT2	Paint at 8-year intervals with 2-coat acrylic, replace at 60 years
	OPT3	Paint at 10-year intervals with high build acrylic, replace at 75 years
BUTYL RUBBER MEMBRANE	OPT1	Wash down periodically with warm soapy water, replace at 20 years, ply sarking OK another 20 yrs. Repair adhesive joints as necessary
	OPT2	Paint on installation with light-coloured reflective paint, repaint every 7 years, replace at 35 years. Repair adhesive joints as necessary
EPDM (sheet adhesive joined)	OPT1	Wash down periodically with warm soapy water, replace at 30 years. Repair adhesive joints as necessary
	OPT2	Paint on installation with light-coloured reflective paint, then repaint every 7 years, replace at 50 years. Repair adhesive joints as necessary

TABLE 2 WALL MAINTENANCE OPTIONS

MODERATE ENVIRONMENT

	OPTIONS	TYPE OF WORK, MAINTENANCE INTERVAL AND LIFE SPAN
CONCRETE BLOCK MASONRY	OPT1	No painting. Repair pointing at 30 years, replace at 50 years
200mm BLOCK	OPT2	Standard acrylic paint 2 coats on installation, repaint every 8 years, replace at 80 years
	OPT3	High-build acrylic paint 3 coats on installation, repaint every 15 years, replace at 90 years
CLAY BRICK	OPT1	Repair pointing every 30 years, replace at 80 years
	OPT2	Standard acrylic paint 2 coats on installation, repaint every 7 years, replace at 100 years
RADIATA WB, FJ RUSTIC OR BEVEL BACK	OPT1	Standard acrylic paint 3 coats initially, 2 coats repaint. Repaint every 8 years, replace at 70 years
150mm BOARD	OPT2	Standard acrylic paint 3 coats initially, 2 coats repaint. Repaint every 10 years + replace some boards, replace at 50 years
CEDAR, RUSTIC or BEVEL BACK	OPT1	Uncoated, no maintenance. Replace at 45 years
200mm BOARD	OPT2	Painted every 3 years with oil-based stain. Replace at 55 years
FIBRE-CEMENT WB	OPT1	Standard acrylic paint 2 coats. Repaint every 8 years, replace at 50 years
240mm BOARD	OPT2	Standard acrylic paint 2 coats. Repaint every 10 years, replace at 45 years
FIBRE-CEMENT SHEET 7.5MM	OPT1	High-build acrylic textured paint 3 coats initially, repaint every 7 years with 1 coat acyrlic, replace at 60 years
incl stopping/ foam seal.	OPT2	High-build acrylic textured paint 3 coats initially. Repaint every 10 years with 1 coat acyrlic, replace at 40 years
uPVC BOARD	OPT1	No maintenance. Replace at 30 years. Wash with soapy water + bleach every 1 to 2 years
	OPT2	Standard acrylic paint 3 coats at 20 years, then at 30 years. Replace at 40 years
	OPT3	Standard acrylic paint 2 coats every 7 years. Replace at 55 years
PLYWOOD, 15MM A-C GRADE SHEET	OPT1	No coating. Replace at 30 years
	OPT2	Standard acrylic 2 coats every 7 years. Replace at 50 years
EIFS	OPT1	Wash/ bleach every year. Paint at 10 years then every 7 years. Replace at 40 years
(40mm EPS)	OPT2	Wash/ bleach every year. Paint at 12 years then every 10 years. Replace at 30 years
STUCCO	OPT1	Standard acrylic 2 coats every 7 years. Replace at 60 years
	OPT2	No paint or maintenance. Replace at 35 years
ALUMINIUM WEATHERBOARD	OPT1	Repaint after 15 years, every 7 years thereafter. Waterblast at 35 years. Continue repainting every 7 years. Replace at 80 years
	OPT2	Repaint after 25 years, every 7 years thereafter. Continue as above. Replace at 70 years
	OPT3	Do not repaint, wash down only. Replace after 50 years

TABLE 3 - ROOFING: LIFE CYCLE COSTS
MODERATE ENVIRONMENT

DISCOUNT RATE= 8% 1.08

	OPTION	INITIAL COSTS ($/SQM)	LIFE YRS	MAINTENANCE (COSTS IN $/SQM) 1 YR	1 CST	2 YR	2 CST	3 YR	3 CST	4 YR	4 CST	5 YR	5 CST	6 YR	6 CST	7 YR	7 CST	8 YR	8 CST	9 YR	9 CST	10 YR	10 CST	MAINTENANCE AS PV	MAINTENANCE AS AN ANNUAL COST.	INITIAL AS AN ANNUAL COST.	TOTAL ANNUAL COST.
CONCRETE TILE	OPT1	47.0	60	20	6.0	40	6.0																	1.6	0.1	3.8	3.92
	OPT2	47.0	75	7	9.0	14	9.0	21	9.0	28	9.0	35	9.0	42	9.0	49	9.0	56	9.0	63	9.0	70	9.0	12.6	1.0	3.8	4.78
	OPT3	47.0	90	15	18.0	30	18.0	45	18.0	60	18.0	75	18.0											8.3	0.7	3.8	4.43
CONCRETE SHINGLES	OPT1	56.0	60	20	6.0	40	6.0																	1.6	0.1	4.5	4.65
	OPT2	56.0	75	7	9.0	14	9.0	21	9.0	28	9.0	35	9.0	42	9.0	49	9.0	56	9.0	63	9.0	70	9.0	12.6	1.0	4.5	5.50
	OPT3	56.0	90	15	18.0	30	18.0	45	18.0	60	18.0	75	18.0											8.3	0.7	4.5	5.15
GALV. CORRUG. STEEL 0.40mm & 0.55mm	OPT1	32.0	50	0	12.0	7	11.0	14	11.0	21	11.0	28	14.0	35	11.0	42	11.0							27.1	2.2	2.6	4.84
	OPT2	32.0	40	15	12.0	22	11.0	29	11.0	36	11.0													7.7	0.6	2.7	3.33
	OPT3	32.0	20																					0.0	0.0	3.3	3.26
PRE-PAINTED GALV. STEEL 0.40mm & 0.55m	OPT1	38.0	50	15	12.0	22	11.0	29	11.0	36	14.0	42	11.0											8.3	0.7	3.1	3.78
	OPT2	38.0	50	15	12.0	25	18.0	35	18.0	45	18.0													8.2	0.7	3.1	3.78
	OPT3	38.0	35																					0.0	0.0	3.3	3.26
ALUMINIUM, CORRUGATED	OPT1	54.0	60	0	12.0	7	11.0	14	11.0	21	11.0	28	14.0	35	11.0	42	11.0	49	11.0	56.0	11.0			27.6	2.2	4.4	6.59
	OPT2	54.0	50	20	12.0	27	11.0	34	11.0	41	11.0	48	11.0											5.5	0.4	4.4	4.86
	OPT3	54.0	40																					0.0	0.0	4.5	4.53
METAL TILES, AGGREGATE COAT	OPT1	40.0	50	15	15.0	22	11.0	29	11.0	36	14.0	42	11.0	48	11.0									9.5	0.8	3.3	4.05
	OPT2	40.0	50	25	18.0	32	11.0	39	11.0	46	11.0													4.4	0.4	3.3	3.63
	OPT3	40.0	35																					0.0	0.0	3.4	3.43
METAL TILES, FACTORY COAT	OPT1	37.0	50	15	11.0	22	11.0	29	11.0	36	11.0	42	11.0	48	11.0									8.1	0.7	3.0	3.68
	OPT2	37.0	50	25	14.0	32	11.0	39	11.0	46	11.0													3.8	0.3	3.0	3.34
	OPT3	37.0	35																					0.0	0.0	3.2	3.17
TIMBER SHINGLES, CEDAR	OPT1	90.0	40	5	6.0	15	5.0	25	5.0	35	5.0													6.0	0.5	7.5	8.05
	OPT2	90.0	25	10	5.0																			2.3	0.2	8.4	8.65
	OPT3	90.0	50	10	13.0	20	13.0	30	13.0	40	13.0													10.7	0.9	7.4	8.23
FIBRE-CEMENT SHINGLES	OPT1	90.0	50	15	8.0	30	8.0	45	8.0															3.6	0.3	7.4	7.65
	OPT2	90.0	65	8	13.0	16	13.0	24	13.0	32	13.0	40	13.0	48	13.0									14.9	1.2	7.3	8.52
	OPT3	90.0	70	15	23.0	30	23.0	45	23.0	60	23.0													10.5	0.8	7.2	8.08
GLASS REINFORCED POLYESTER SHINGLE	OPT1	52.0	20																					0.0	0.0	5.3	5.30
	OPT2	52.0	40	7	18.0	14	18.0	21	18.0	28	18.0	35	18.0											23.5	2.0	4.4	6.33
SLATE BUTYL RUBBER	OPT1	143.0	20																					0.0	0.0	14.6	14.56
	OPT2	143.0	35	7	8.0	14	8.0	21	8.0	28	8.0													9.9	0.9	12.3	13.12
FIBRE-CEMENT, CORRUGATED	OPT1	95.0	40	15	3.0	30	3.0																	1.2	0.1	8.0	8.07
	OPT2	95.0	60	7	8.0	14	8.0	21	8.0	28	8.0	35	8.0	42	8.0	49	8.0	56	8.0					11.1	0.9	7.7	8.57
	OPT3	95.0	75	10	18.0	20	18.0	30	18.0	40	18.0	50	18.0	60	18.0	70	18.0							15.5	1.2	7.6	8.86
BUTYL RUBBER MEMBRANE	OPT1	95.0	20																					0.0	0.0	9.7	9.68
	OPT2	95.0	35	0	8.0	7	8.0	14	8.0	21	8.0	28	8.0											17.9	1.5	8.2	9.69
		95.0																									
EPDM (sheet adhesive joined)	OPT1	130.0	30																					0.0	0.0	11.5	11.55
	OPT2	130.0	50	0	8.0	7	8.0	14	8.0	21	8.0	28	8.0	35	8.0	42	8.0							18.8	1.5	10.6	12.16

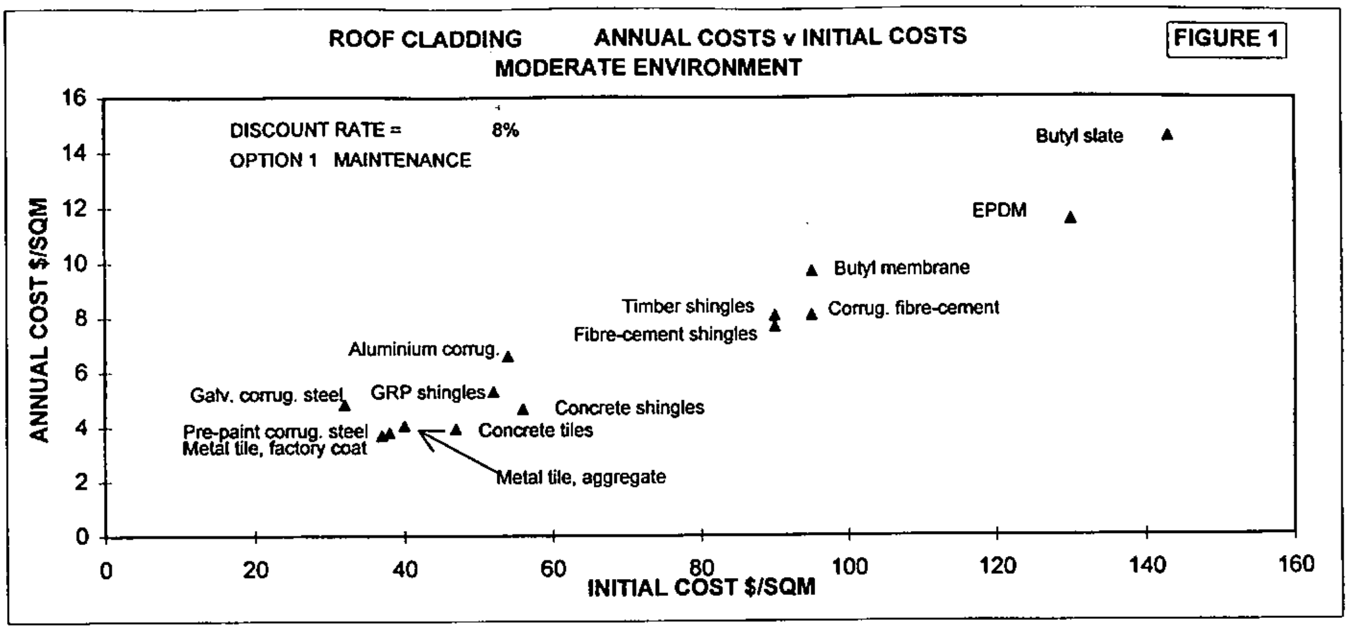
Note: Initial costs include, if required, purlins, battens, building paper, and ply sarking.

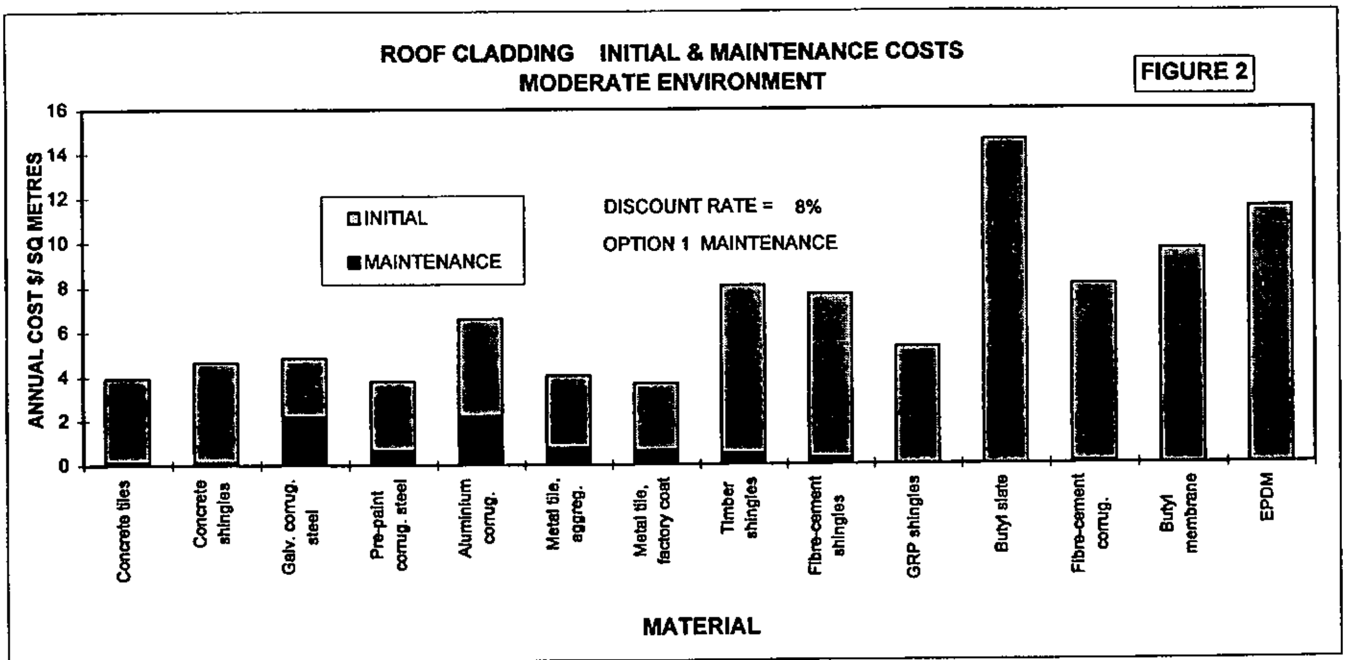
TABLE 4 WALLS: LIFE CYCLE COSTS

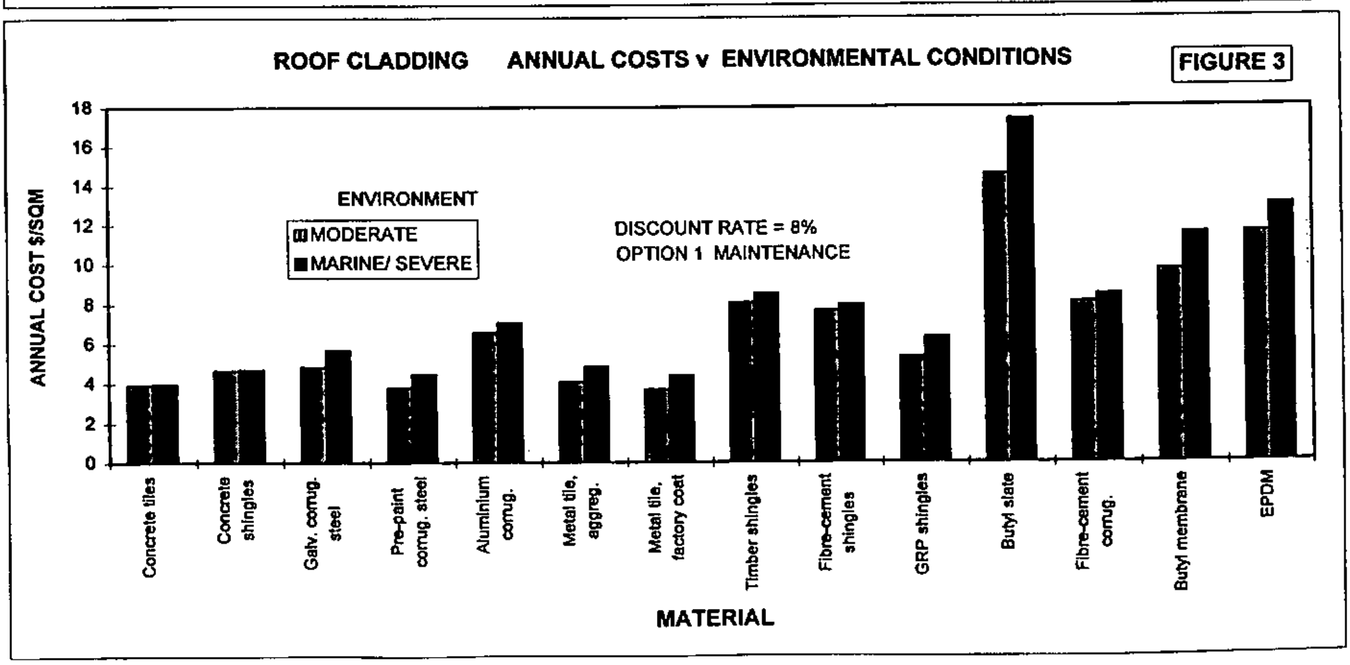
MODERATE ENVIRONMENT

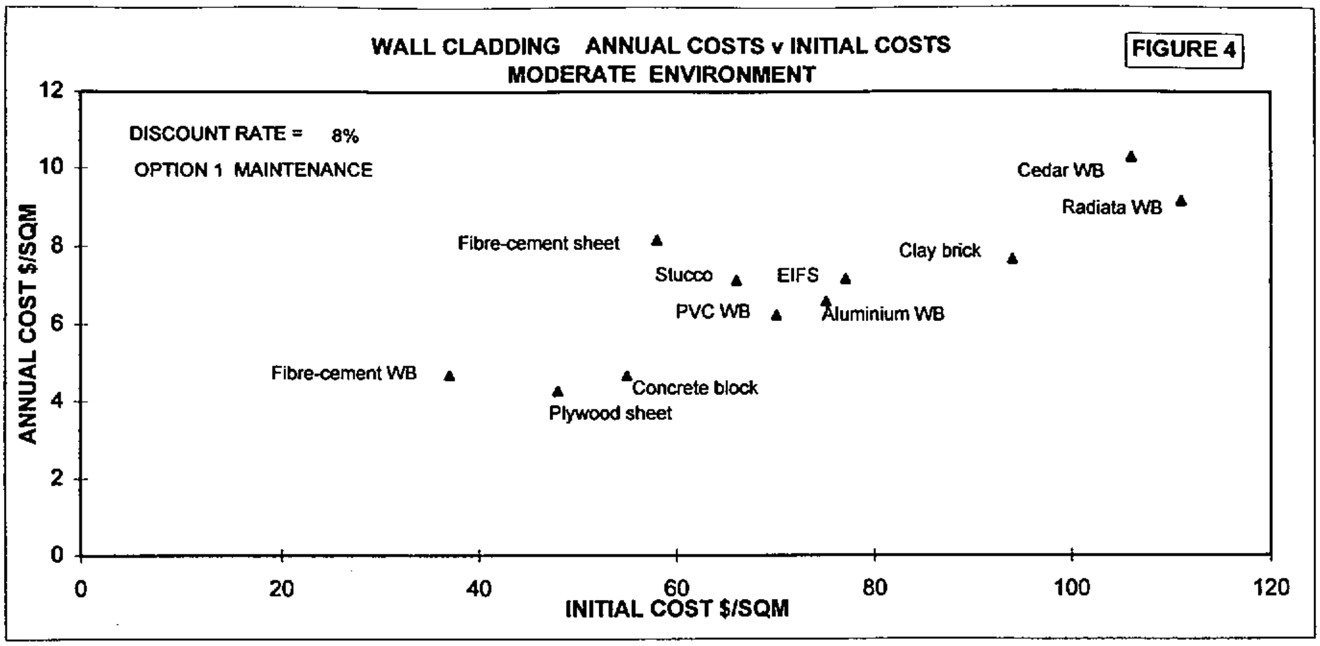
DISCOUNT RATE= 8%

	OPTION	INITIAL COSTS ($/SQM)	LIFE YRS	MAINTENANCE (COSTS IN $/SQM) 1		2		3		4		5		6		7		8		9		10		MAINTENANCE AS PV	MAINTENANCE AS AN ANNUAL COST.	INITIAL AS AN ANNUAL COST.	TOTAL ANNUAL COST
				YR	CST	YR	CST	YR	CST	YR	CST	YR	CST	YR	CST	YR	CST	YR	CST	YR	CST	YR	CST				
CONCRETE BLOCK MASONRY	OPT1	55.0	50	30	20.0																			2.0	0.2	4.5	4.66
200mm BLOCK	OPT2	55.0	80	0	8.0	8	8.0	16	8.0	24	8.0	32	8.0	40	8.0	48	8.0	56	8.0	64	8.0	72	8.0	17.4	1.4	4.4	5.80
	OPT3	55.0	90	0	16.5	15	16.5	30	16.5	45	16.5	60	16.5	75	16.5									24.1	1.9	4.4	6.33
CLAY BRICK	OPT1	94.0	80	40	30.0	60	30																	1.7	0.1	7.5	7.67
	OPT2	94.0	100	0	8.0	7	8.0	14	8.0	21	8.0	28	8.0	35	8.0	42	8.0	49	8.0	56	8.0	80	48.0	19.2	1.5	7.5	9.06
RADIATA WB, FJ RUSTIC OR BEVEL BACK	OPT1	106.0	70	0	11.0	7	8.0	14	8.0	21	8.0	28	8.0	35	8.0	42	8.0	49	8.0	56	8.0	63	8.0	22.1	1.8	8.5	10.30
150MM BOARD	OPT2	106.0	50	0	11.0	10	14.5	20	14.5	30	14.5	40	14.5											22.9	1.9	8.7	10.54
CEDAR, RUSTIC or BEVEL BACK	OPT1	111.0	45																					0.0	0.0	9.2	9.17
200 mm BOARD	OPT2	111.0	55	0.0	6.5	3	6.5	6	6.5	9	6.5	12	6.5	18	20	27	20	36	20	45	20			30.7	2.5	9.0	11.51
FIBRE-CEMENT WB	OPT1	37.0	50	0	11.0	8	8.0	16	8.0	24	8.0	32	8.0	40	8.0	48	8.0							20.2	1.6	3.0	4.67
HARDIPLANK	OPT2	37.0	45	0	11.0	10	8.0	20	8.0	30	8.0													17.2	1.4	3.1	4.48
FIBRE-CEMENT SHEET 7.5MM	OPT1	58.0	60	0	36.0	7	5.0	14	5.0	21	5.0	28	5.0	35	5.0	42	5.0	49	5.0	56	5.0			42.9	3.5	4.7	8.15
incl stopping/ foam seal.	OPT2	58.0	40	0	36.0	10	5.0	20	5.0	30	5.0													39.9	3.3	4.9	8.21
uPVC BOARD	OPT1	70.0	30																					0.0	0.0	6.2	6.22
	OPT2	70.0	40	20	12.0	30	12.0																	3.8	0.3	5.9	6.19
	OPT3	70.0	55	0	11.0	7	8.0	14	8.0	21	8.0	28	8.0	35	8.0	42	8.0	49	8.0					21.9	1.8	5.7	7.46
PLYWOOD, 15MM A-C GRADE SHEET	OPT1	48.0	30																					0.0	0.0	4.3	4.26
	OPT2	48.0	50	0	11.0	7	8.0	14	8.0	21	8.0	28	8.0	35	8.0	42	8.0	49	8.0					21.9	1.8	3.9	5.72
EIFS	OPT1	77.0	40	10	8.0	17	8.0	24	8.0	31	8.0	38	8.0											8.3	0.7	6.5	7.15
40mm EPS	OPT2	77.0	30	12	11.0	22	8.0																	5.8	0.5	6.8	7.36
STUCCO	OPT1	66.0	60	0	11.0	7	8.0	14	8.0	21	8.0	28	8.0	35	8.0	42	8.0	49	8.0	56	8.0			22.1	1.8	5.3	7.11
	OPT2	66.0	35																					0.0	0.0	5.7	5.66
ALUMINIUM WEATHERBOARD	OPT1	75.0	80	15	11.0	22	8.0	29	8.0	36	8.0	43	8.0	50	8.0	57	8.0	64	8.0	71	8.0	78	8.0	7.0	0.6	6.0	6.57
	OPT2	75.0	70	25	11.0	32	8.0	39	8.0	46	8.0	53	8.0	60	8.0	67	8.0							3.2	0.3	6.0	6.28
	OPT3	75.0	50																					0.0	0.0	6.1	6.13

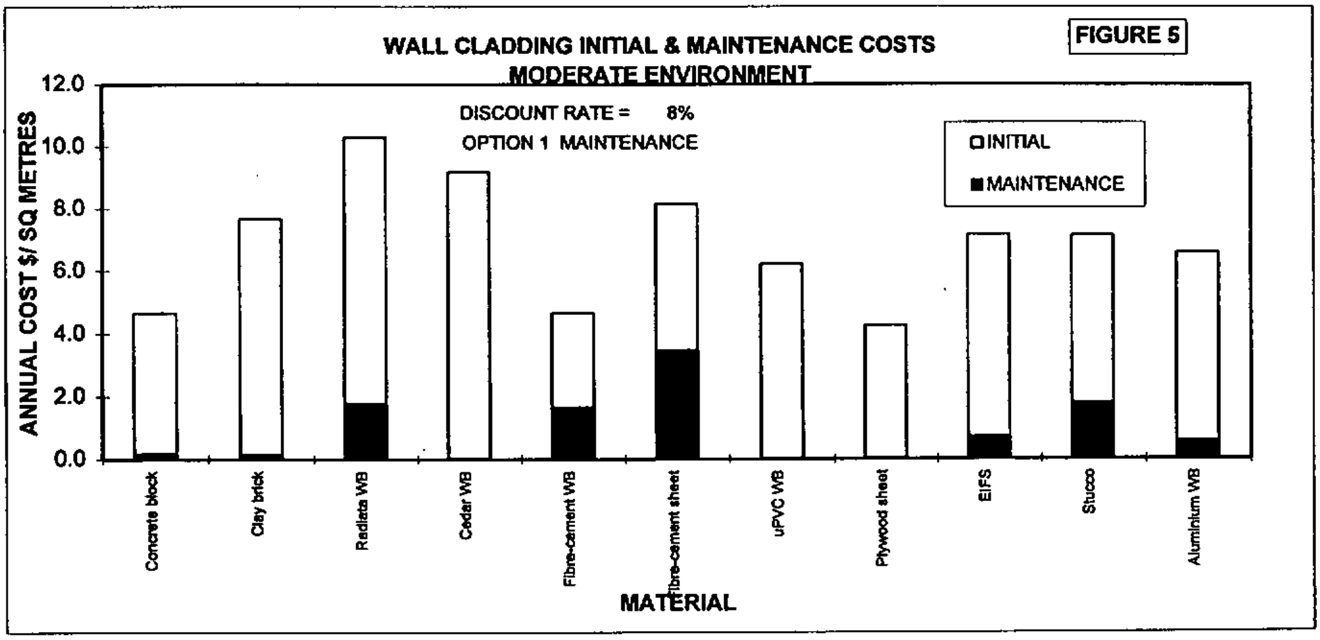

ROOF CLADDING ANNUAL COSTS v INITIAL COSTS
MODERATE ENVIRONMENT
FIGURE 1
DISCOUNT RATE = 8%
OPTION 1 MAINTENANCE
Butyl slate
EPDM
Butyl membrane
Timber shingles
Corrug. fibre-cement
Fibre-cement shingles
Aluminium corrug.
Galv. corrug. steel
GRP shingles
Concrete shingles
Pre-paint corrug. steel
Metal tile, factory coat
Concrete tiles
Metal tile, aggregate
ANNUAL COST $/SQM
INITIAL COST $/SQM


ROOF CLADDING INITIAL & MAINTENANCE COSTS
MODERATE ENVIRONMENT
FIGURE 2
INITIAL
MAINTENANCE
DISCOUNT RATE = 8%
OPTION 1 MAINTENANCE
ANNUAL COST $/ SQ METRES
Concrete tiles
Concrete shingles
Galv. corrug. steel
Pre-paint corrug. steel
Aluminium corrug.
Metal tile, aggreg.
Metal tile, factory coat
Timber shingles
Fibre-cement shingles
GRP shingles
Butyl slate
Fibre-cement corrug.
Butyl membrane
EPDM
MATERIAL

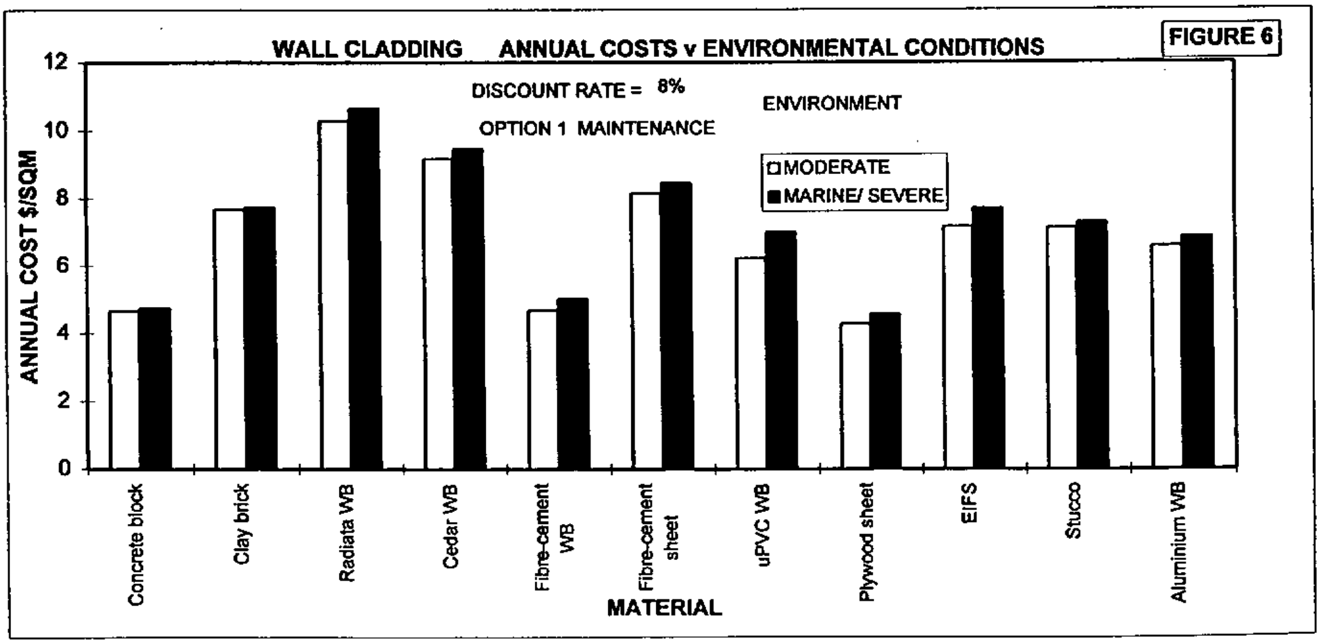

ROOF CLADDING ANNUAL COSTS v ENVIRONMENTAL CONDITIONS
FIGURE 3
ENVIRONMENT
MODERATE
MARINE/ SEVERE
DISCOUNT RATE = 8%
OPTION 1 MAINTENANCE
ANNUAL COST $/SQM
Concrete tiles
Concrete shingles
Galv. corrug. steel
Pre-paint corrug. steel
Aluminium corrug.
Metal tile, aggreg.
Metal tile, factory coat
Timber shingles
Fibre-cement shingles
GRP shingles
Butyl slate
Fibre-cement corrug.
Butyl membrane
EPDM
MATERIAL



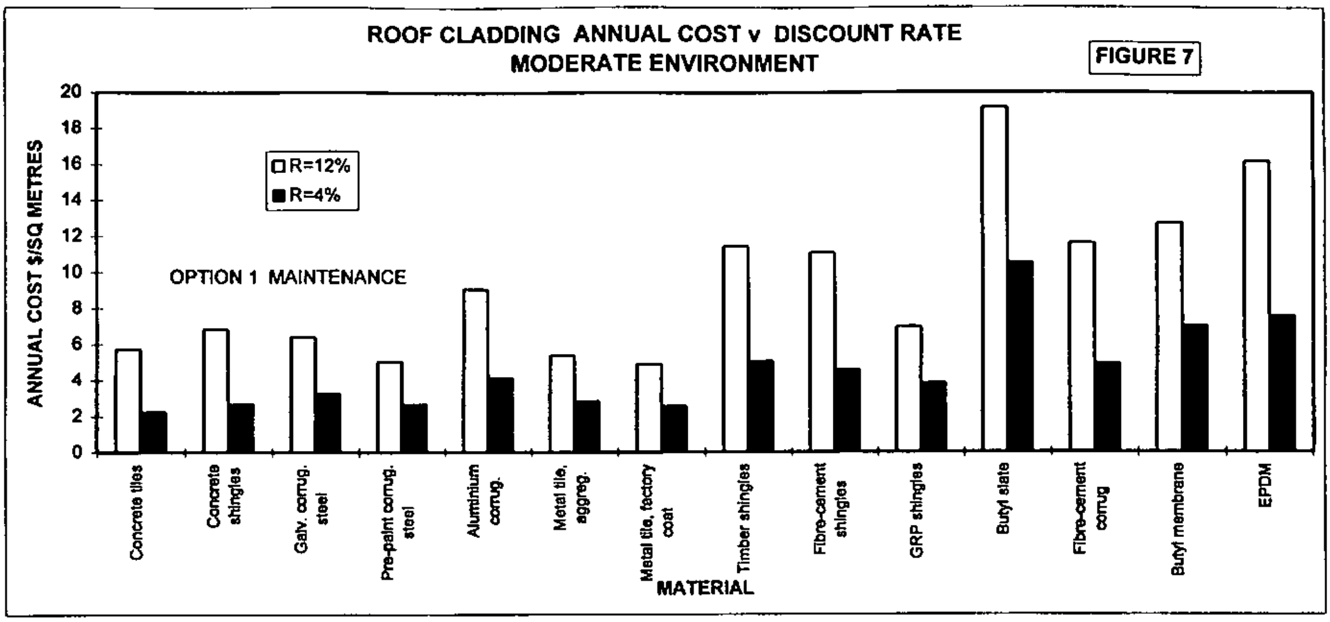
WALL CLADDING ANNUAL COSTS v INITIAL COSTS
MODERATE ENVIRONMENT
FIGURE 4
DISCOUNT RATE = 8%
OPTION 1 MAINTENANCE
ANNUAL COST $/SQM
INITIAL COST $/SQM
Cedar WB
Radiata WB
Fibre-cement sheet
Clay brick
Stucco
EIFS
PVC WB
Aluminium WB
Fibre-cement WB
Concrete block
Plywood sheet

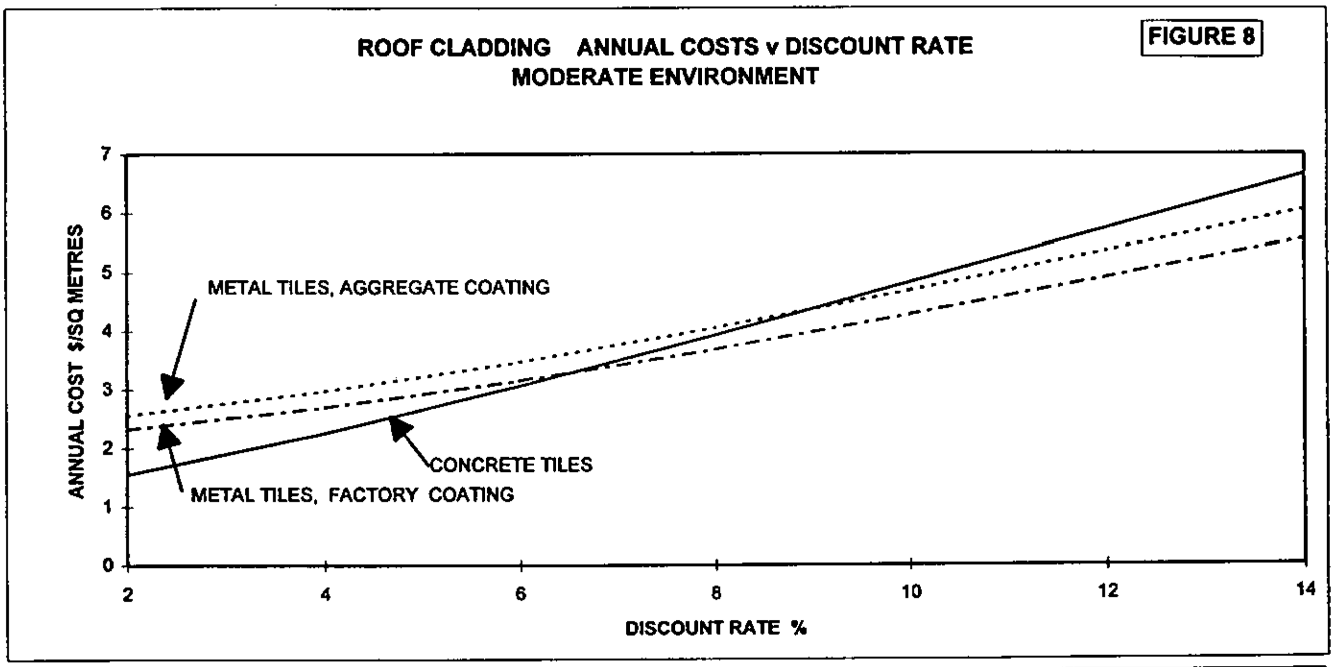


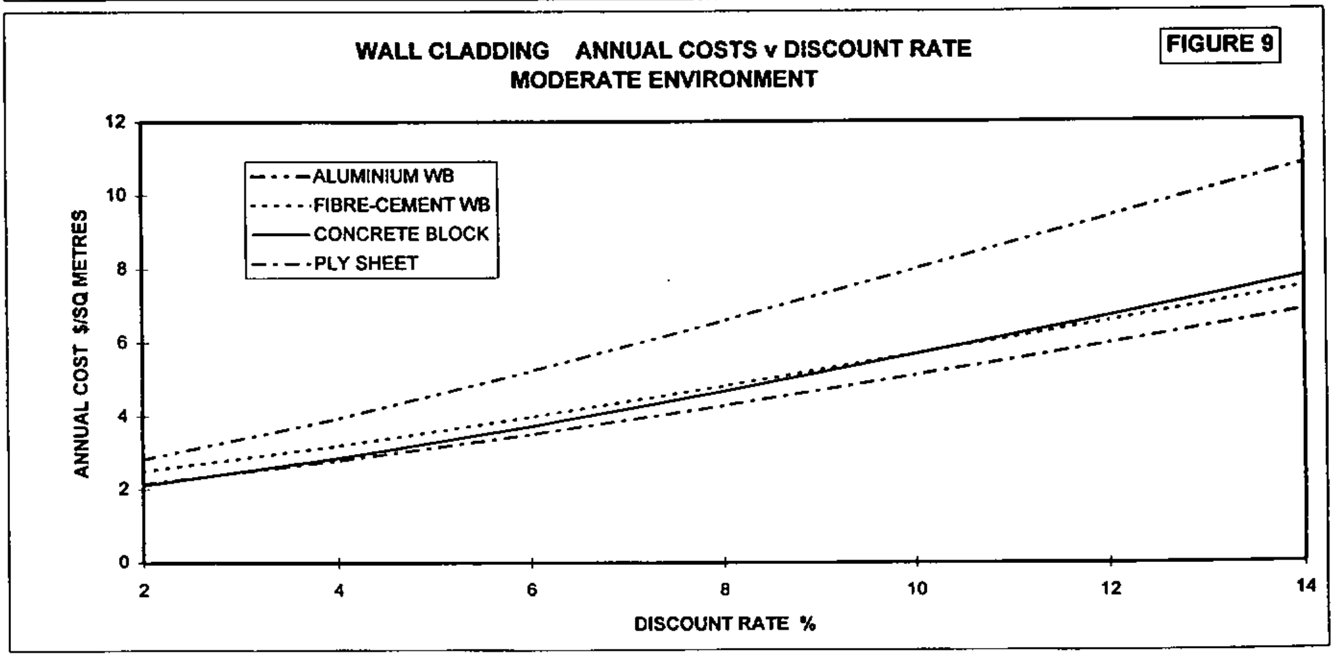
WALL CLADDING INITIAL & MAINTENANCE COSTS
MODERATE ENVIRONMENT
FIGURE 5
DISCOUNT RATE = 8%
OPTION 1 MAINTENANCE
INITIAL
MAINTENANCE
ANNUAL COST $/ SQ METRES
Concrete block
Clay brick
Radiata WB
Cedar WB
Fibre-cement WB
Fibre-cement sheet
uPVC WB
Plywood sheet
EIFS
Stucco
Aluminium WB
MATERIAL

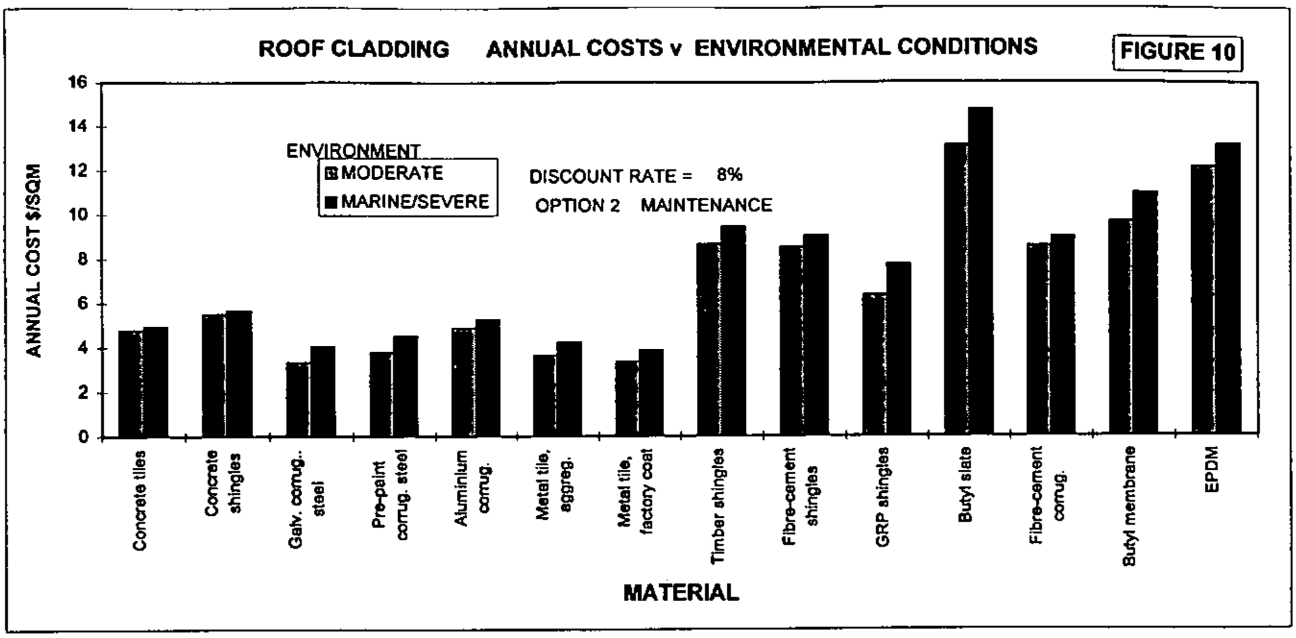


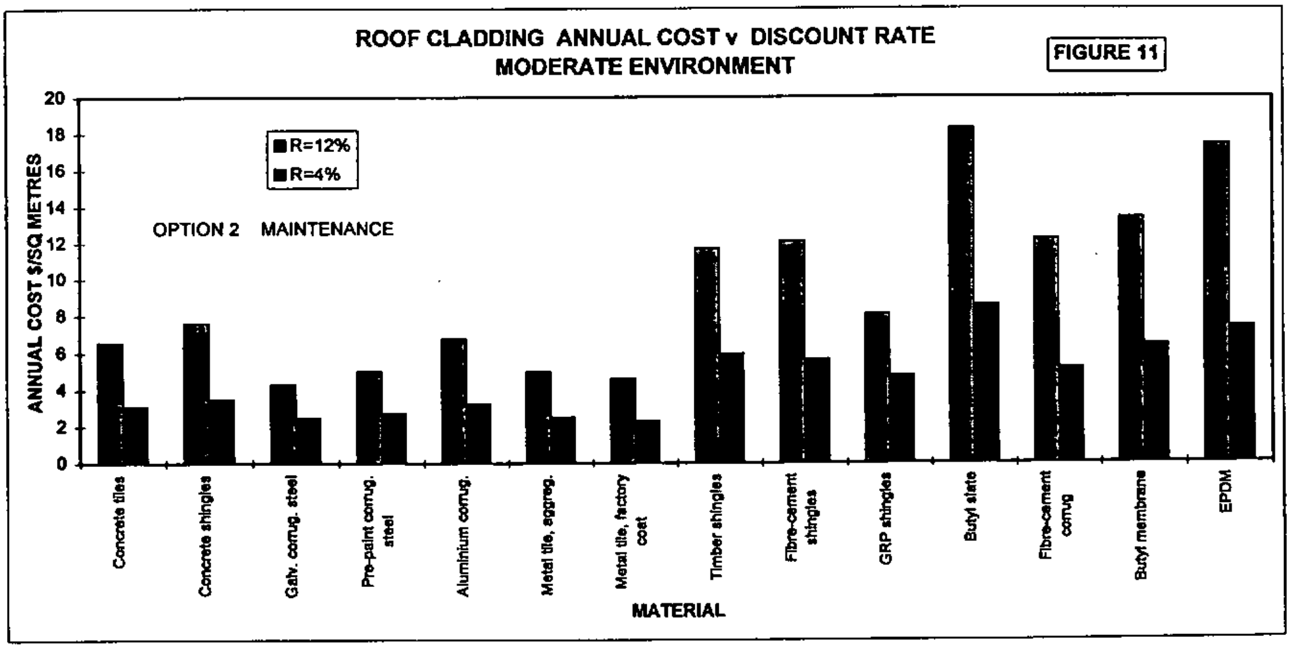
WALL CLADDING ANNUAL COSTS v ENVIRONMENTAL CONDITIONS
FIGURE 6
DISCOUNT RATE = 8%
OPTION 1 MAINTENANCE
ENVIRONMENT
MODERATE
MARINE/ SEVERE
ANNUAL COST $/SQM
Concrete block
Clay brick
Radiata WB
Cedar WB
Fibre-cement WB
Fibre-cement sheet
uPVC WB
Plywood sheet
EIFS
Stucco
Aluminium WB
MATERIAL


ROOF CLADDING ANNUAL COST v DISCOUNT RATE
MODERATE ENVIRONMENT
FIGURE 7
ANNUAL COST $/SQ METRES
R=12%
R=4%
OPTION 1 MAINTENANCE
Concrete tiles
Concrete shingles
Galv. corrug. steel
Pre-paint corrug. steel
Aluminium corrug.
Metal tile, aggreg.
Metal tile, factory coat
Timber shingles
Fibre-cement shingles
GRP shingles
Butyl slate
Fibre-cement corrug
Butyl membrane
EPDM
MATERIAL


ROOF CLADDING ANNUAL COSTS v DISCOUNT RATE
MODERATE ENVIRONMENT
FIGURE 8
ANNUAL COST $/SQ METRES
METAL TILES, AGGREGATE COATING
CONCRETE TILES
METAL TILES, FACTORY COATING
DISCOUNT RATE %


WALL CLADDING ANNUAL COSTS v DISCOUNT RATE
MODERATE ENVIRONMENT
FIGURE 9
ANNUAL COST $/SQ METRES
ALUMINIUM WB
FIBRE-CEMENT WB
CONCRETE BLOCK
PLY SHEET
DISCOUNT RATE %


ROOF CLADDING ANNUAL COSTS v ENVIRONMENTAL CONDITIONS
FIGURE 10
ANNUAL COST $/SQM
ENVIRONMENT
MODERATE
MARINE/SEVERE
DISCOUNT RATE = 8%
OPTION 2 MAINTENANCE
Concrete tiles
Concrete shingles
Galv. corrug. steel
Pre-paint corrug. steel
Aluminium corrug.
Metal tile, aggreg.
Metal tile, factory coat
Timber shingles
Fibre-cement shingles
GRP shingles
Butyl slate
Fibre-cement corrug.
Butyl membrane
EPDM
MATERIAL


ROOF CLADDING ANNUAL COST v DISCOUNT RATE
MODERATE ENVIRONMENT
FIGURE 11
ANNUAL COST $/SQ METRES
R=12%
R=4%
OPTION 2 MAINTENANCE
Concrete tiles
Concrete shingles
Galv. corrug. steel
Pre-paint corrug. steel
Aluminium corrug.
Metal tile, aggreg.
Metal tile, factory coat
Timber shingles
Fibre-cement shingles
GRP shingles
Butyl slate
Fibre-cement corrug
Butyl membrane
EPDM
MATERIAL

8.0 APPENDIX

8.1 Life cycle cost analysis

The principles of life cycle cost analysis are well known, and suitable texts for further information are listed in references (1), (2) and (3). In brief, the technique involves the idea that a $1 expenditure now costs more than if it were deferred, say 5 years into the future. Whereas in the first case $1 is needed now, in the second case a lesser amount can be set aside now to earn interest so that it amounts to $1 in 5 years' time. The amount to set aside now is that which, when compounded at the appropriate interest rate (or discount rate), will exactly equal $1 in 5 years' time. The compound factor is given by:

$(1 + r)^5 = 1.611$ for $r = 10\%$.

Hence, the amount to be set aside now is only $1/1.611 = 62 cents. Or, in other words, an expenditure of $1 in 5 years' time is only worth 62 cents in today's values.

The technique used in this study is to bring all costs to present values and then to spread these costs annually across the life of the material. The relevant formulae are:

$$PV = C_i + C_1 / (1+r) + C_2 /(1+r)^2 + C_3 /(1+r)^3 + \ldots\ldots + C_N /(1+r)^N$$

where PV = present value of the future cost streams $/sqm.
C_i = Initial cost of material $/ sq metres.
C_1, C_2, C_3 C_N = maintenance costs, $/sqm, in year 1, 2, 3...... N.
r = discount rate.
N = life of material.

The present value is then spread over the life of the material, as an equivalent annual cost, using the following formula:

A = PV * CRF
where A = annual equivalent life cycle cost $/sqm
CRF(r/N) = Capital recovery factor for N years and discount rate r,
$CRF(r/N) = r(1+r)^N/((1+r)^N-1)$

This equivalent annual cost is similar in concept to mortgage repayments, because maintenance has been brought to present-day values (equivalent to an amount borrowed) and is then spread in equivalent annual costs (or mortgage repayments) over the life of the material.

The discount rate is an important factor affecting the relative advantage of low-maintenance, high-cost materials, against high-maintenance, low-cost materials. For domestic buildings the relevant rate is the cost of finance to the home owner, namely the mortgage rate. If the real rate is used (ie the nominal rate less expected inflation) then the effect of inflation on future maintenance costs can be ignored. For the purposes of this study the interest rate used is the long-term, inflation-adjusted interest rate and is estimated to be around 8%. This is based on an assumed average 10-year Government stock rate of 8.0%, (currently it is around 7.5% but is likely to increase due to increased coalition Government expenditure). To this is added a 2.5% risk factor for home mortgages less an average inflation rate over the next few years of 3% per annum, giving a 7.5% real mortgage rate for the next few years. This has been rounded up to 8%. Note that with current house mortgages at around 10.6%, less 2.1% inflation, the real rate is 8.5%, so in the long-term only a small drop is expected.

The maintenance regimes included in the study are given in Tables 1 and 2 and the life cycle costs in Tables 3 and 4. Maintenance involves cleaning, water blasting, replacing damaged cladding and renewing protective coatings. The first item has been ignored in the costings as it is considered part of a home owner's normal cleaning routine, ie external washing down including exterior windows, and general section maintenance. However, the other items involve significant expenditure on materials and are relatively infrequent activities. In many cases the homeowner would contract out these items and so commercial rates have been used. The rates used are in Table 5 .

8.2 Environmental conditions

The definitions of environmental conditions (defined by how the materials perform) are:

Metal substrate - As defined in AS/NZS 2312 (7). Moderate conditions are a mild steel first year corrosion rate of between 10 to 25µm per annum. Much of New Zealand is within this zone, which can be described as lightly marine influenced. A marine environment is a mild steel corrosion rate of 25 to 50µm per annum and is usually within a few hundred metres of the coastline. For the purposes of this study it also includes industrial areas and geothermal zones involving chemical discharges to the atmosphere.

Timber, concrete, fibre-cement, polystyrene (EIFS) substrate - No particular agreed measure is available but two main factors influence the performance of the substrate and its coatings, namely moisture and temperature. For the purposes of this study it is assumed that most of New Zealand lies within the moderate zone and it is only regions of high relative humidity, over 83%, 9am annual average, or which have over 2000 mm of rainfall per year, that are in the severe environment. Where failure occurs in EIFS it is likely to be at penetrations and flashings, where moisture is driven into the polystyrene substrate. Severe conditions for EIFS are likely to be similar to those for timber, and fibre-cement.

Butyl rubber, EPDM, GRP - No particular agreed measure is available but performance is largely governed by the degree of exposure to UV radiation. Peak temperatures are also important. UV radiation decreases with an increase in latitude and increases with an increase in altitude. Most of the country is in a moderate environment but alpine areas and northern locations with high summer temperatures, such as inland Bay of Plenty or Hawkes Bay, or lower latitudes with higher UV in the upper half of the North Island, are probably in a severe environment.

Table 5 *Painting costs*

PAINTING / REPAIR COSTS	
PAINT WALL	**$/Sqm**
Weatherboard / ply:- Primer + 2 coats acrylic	11.0
Weatherboard / stucco / EIFS / ply / block :- 2 coats acrylic	8.0
Cedar WB:- Oil-based stain 2 coats	6.5
Stucco:- High-build acrylic, 3 coats	15.5
Blockwork:- High-build acrylic, 3 coats	16.5
Fibre-cement sheet:- High-build medium texture	24.0
Fibre-cement sheet:- Jointing / flushing	12.0
Fibre-cement sheet:- Repaint textured finish, 1 coat acrylic	5.0
Repair pointing in clay brick	20.0
Repair pointing in concrete block	30.0
Replace 2% of weatherboards @ x3 new rate (10yr intervals)	6.5
PAINT ROOF	
Metal roof:- Etch primer + 2 coats acrylic paint	12.0
Pre-painted steel roof:- Clean, repaint 2 coats acrylic	11.0
Metal roof:- High-build acrylic paint	18.0
Concrete shingles / tiles:- 2 coats acrylic	8.0
Butly / EPDM:- 2 coats acrylic	8.0
Fibre-cement corrugated:- 2 coats acrylic	8.0
Cedar / GRP shingles:- 2 coats acrylic	8.0
Waterblast cleaning	3.0
Repointing tiles (20yr intervals)	3.0
Replace cracked GRP shingles (7yr intervals)	10.0
Replace cracked cedar / fibre cement shingles (10yr intervals)	5.0
Cost base year 1995/96.	

The life cycle costs under severe environmental conditions, i.e severe/marine environment impacts, were derived from the moderate case with a one factor adjustment to the time periods. This adjustment factor was a number between 0 and 1 and was applied to the maintenance return period and the life of the material. It is assumed to represent all the increased environmental impacts of a marine/severe environment. The factors are shown in Table 6. They are not based on any particular specific systematic research but are broad estimates based on BRANZ experience over the past 25 years of researching the durability of materials under various conditions.

Table 6 Environmental adjustment factors

ENVIRONMENTAL FACTOR		
SUBSTRATA	**FACTOR (1)**	**GOVERNING IMPACT**
CONCRETE / CLAY	0.9	Moisture / shade
STEEL	0.7	Marine salts
ALUMINIUM	0.8	Marine salts
TIMBER	0.8	Moisture
FIBRE CEMENT	0.8	Moisture
EIFS	0.8	Moisture / wind
FIBREGLASS	0.7	UV radiation / temperature
PVC / BUTYL / EPDM	0.7	UV radiation / temperature

(1) The factor is applied to the moderate environment material life and maintenance return periods to give the marine / servere environment life and maintenance periods. It is an approximation of average effects and will vary widely between uses of the same material.

For example, the concrete tile roof under option 1 maintenance would, in a severe environment, have a life of 54 years, and maintenance costs of $6/sq metre at year 18 and at year 36. Under moderate conditions the life is 60 years and the maintenance is unchanged at $6/sq metre at years 20 and 40. These values are obtained by using the concrete environmental factor from Table 6 and multiplying it by the maintenance periods and cladding life given in Table 1 and Table 3 for concrete tiles.

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