Stucco

An investigation of Building Material Failures

Prepared for

Building Research Association of New Zealand (BRANZ)

In conjunction with the requirements of **BBSc 442 Building Materials Performance**

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Executive Summary

The last three decades has seen an increase in the use of innovative construction systems in the New Zealand building industry including an increased use of stucco as a cladding system. The number of stucco related weathertightness failures has also increased. The Building Research Association of New Zealand (BRANZ) has been recording reported building failures and has a building failures database. The information currently available in the BRANZ database does not easily allow access to the reasons for failure with regard to actual case studies. These need to be clearly identified and analysed in order to provide the industry with research based advice on the weathertightness of stucco cladding.

The BRANZ Site Visit Database (BRANZ dBase 1994-2001) was used to provide the dataset of stucco related weathertightness building failures. An e-matrix was generated to provide a means of assessing the issues associated with stucco failure and to allow a graphical representation of the data to be generated for further analysis. This also allowed more specific analysis (sub-issues) to be conducted from each of these issues. The results obtained highlight the main issues associated with the failures recorded (Figure1.01).

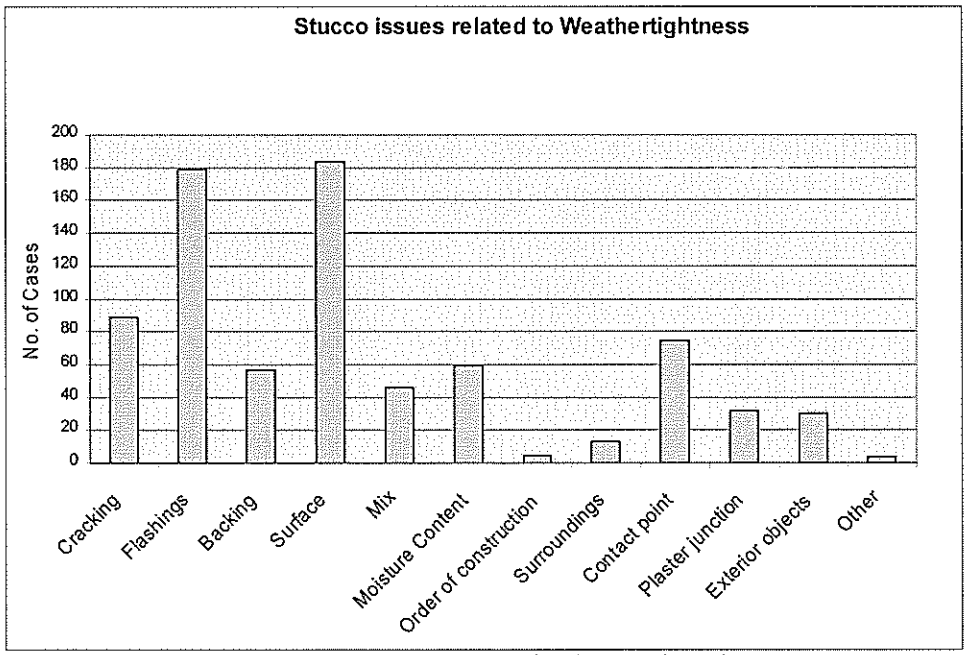

Figure 1.01 Stucco issues related to weathertightness

The investigation highlighted many fundamental issues with respect to current stucco practice. From this investigation, it is apparent that the basics principles of good stucco practice are not being adhered to. A high proportion of stucco related weathertightness failures are a result of poor workmanship, while others relate to design and detailing. In order to produce a cladding system with a low probability of failure, the stucco industry needs to re-examine current design, detailing and workmanship practice. Education and up-skilling of the profession and trades people will increase the level of design, detailing and workmanship, while greater enforcement of industry standards would ensure that good practice is being carried out.

- Educate the profession
- Up skill trades people
- Enforce standards

1. Introduction

Stucco is just one of the many claddings used in the domestic construction in New Zealand. If applied properly, Stucco can provide a weathertight finish which lasts for years. Just like any other cladding, there have been cases reported where the stucco has failed with regard to weathertightness. This report will investigate stucco related weathertightness issues.
The attention to the weathertightness of buildings is essential in order to prevent damage to property and people, but all too often the awareness and implications of its failure are overlooked.

Weathertightness

Weathertightness is the ability to prevent the penetration of the weather through the building envelope. Water penetration, one result of weathertightness failure often causes considerable damage. This failure can range from a simple change in colour, to corrosion, and/or the complete breakdown of building materials. This failure can be hard to trace and diagnose due to its unpredictable nature and varied circumstances from which the problem originates. Its affect on the appearance and the strength of a material, or materials can be considerable. A building which is inadequately designed or not constructed in accordance with the design drawings and specifications can often result in a weathertightness failure.

The trend of weathertightness related cases has increased from 14% in 1985 to 22% in 2000(Bassett 2001, Fig 2), resulting in the investigation of building failures by the Building Research Association of New Zealand (hereafter referred to as BRANZ). Failures can be attributed to particular types of construction. The most frequent failures are identified in the BRANZ database. Preliminary investigation indicates 28% of cladding system failures are stucco related (Bassett 2001, Fig 6).

Problem Statement

Weathertightness is an issue that affects the appearance and structure of the building and possibly the health of its occupants. There could be a number of contributing factors, but to date there has not been a comprehensive analysis of the problem.

Objective

The objective is to determine the probable cause of weather tight failures in stucco cladding systems. The outcome will identify preventative solutions and suggest measures to avoid further failures.

Research Approach

To achieve this objective the BRANZ Site Visit Database 1994-2001, will be used as the basis to explore stucco related building failures. The database is likely to underestimate the extent of the problem as it is comprised from site inspections and a small number of pre-purchase inspections, but should provide a reliable understanding of the relative occurrence of the problems. By using this database, a breakdown of the weathertightness issues in direct relation to the cladding system of stucco can be obtained. The cause of the failures can then be specifically grouped and quantified to reveal associated trends. The dataset to be utilised is primarily made up of failure investigation site visits, while a limited few are pre-purchase inspections.

2. Background

This chapter will provide a clear definition of weathertightness and investigate relevant publications and recent media reports, which have raised the public awareness of the problem. It will also investigate the extent to which stucco cladding has been utilised over the years and will highlight the requirement for this study

General Definition

Stucco refers to solid plaster claddings of Portland cement and sand (often containing lime, plasticisers or other add mixtures), applied over a rigid or non-rigid backing fixed to light timber or steel framing and reinforced with metal wire mesh or lath. (Ten Broeke & Hardie 1996).

Review

Reviewed Publications

Good Stucco Practice (Ten Broeke and Hardie) was prepared in response to the industries request for a simple document describing how to produce good stucco finishes with a low probability of failure. The publication runs through aspects of stucco, ranging from its definition, its ability to act as a cladding, the design required to allow stucco to work effectively, to the type of surface finishes and its performance in fire. The book is based upon opinions of experienced plasterers and on the readily available technical information. The contents are aimed at an industry field were information on alternative backing materials, reinforcing and mix components were seen to be lacking at the time of this 1996 publication.

At the time of this report, an introductory *Analysis of BRANZ Site Visit Records in relation to Weathertightness Problems* (Bassett 2001, Draft) was being undertaken. This

essentially begins to identify the key area of failures based on key word coincidences.
The trends of keyword use provide 'hotspots' where more specific investigation is required.

Standards New Zealand
NZS 4251:1998 Cement plasters for walls, ceilings and soffits.
This has been updated from the previous 1974 standard. The standard, if followed correctly will provide a durable and virtually crack free plaster system. The standard does provide full window flashing details, but these still need careful attention to detail. This Standard is essential for everyone involved in the design, construction and approval of buildings utilising solid plaster.

An *Auckland House Cladding Survey*, (Murphy, C et al)prepared for the Building Industry Authority (BIA) of Wellington by the UNITEC Institute of Technology, looks at the Auckland Housing market and investigates the relationship between the wall cladding system(s) adopted and the type and frequency of any defect or omission. It also investigates the relationship between age of the cladding system and the type and frequency of the defect of omission. From this, it is apparent that stucco is becoming more popular in its use, but so have the numbers of defects reported against this cladding method.

The *Building and Construction Industry Training Organisation* (hereafter referred to as BCITO, http://www.bcito.org.nz/index.htm) provides qualifications in the area of exterior plastering. Three qualifications in direct relation to solid plastering are currently offered, The National Certificate in Solid Plastering, The National Certificate in Proprietary Plaster Cladding Systems (fibre Cement and External insulation and Finishing Systems – EIFS) and the National Certificate in proprietary Plaster cladding systems (Advanced). To complete these qualifications the trainee needs to be linked to the supplier whose products are being used. The suppliers will be the ones confirming the competent use of their products and systems.

Current Raised awareness

The public awareness of the weathertightness problem has been raised due to the recent reporting in local papers of weathertightness related issues.

> "The skills and habits of some plasterers could at best be described as dubious. For example, the best excuse I have been given for a lack of plaster curing was - "I couldn't wet the plaster – there were too many leaks around the windows." The biggest problem with all these claddings is their appearance and versatility, which almost invites abuse."(O'Sullivan)
> "Christchurch builder Dax Lowen said 80% of the houses he worked on involved stucco sprayed on to concrete blocks, polystyrene or backer"(Robson)
> "The problems are in the houses with the smooth exterior look, rather than the traditional brick or weatherboards"... "There has been a rapid development of these building systems and some very adventurous designs which can be difficult to weather proof"(Gamble & Corbett)
> "Traditional houses with eves don't give problems. Houses without eves, flat roofs and balconies, have a much higher tendency to have a problem" (Robson)
> "... new homes may be rotting because of water seeping through new "chilli-bin" claddings... In the old days everybody took pride in what they did, now no one gives a damn"(Gamble & Corbett).

The failure of stucco is only one of a number of building failures identified by the Branz database.

Cladding Use Comparisons

The following graph, Figure 2.01 provides a comparison between the use of stucco, EIFS, Textured Fibre Cement Board (TexFc) and alternative claddings.

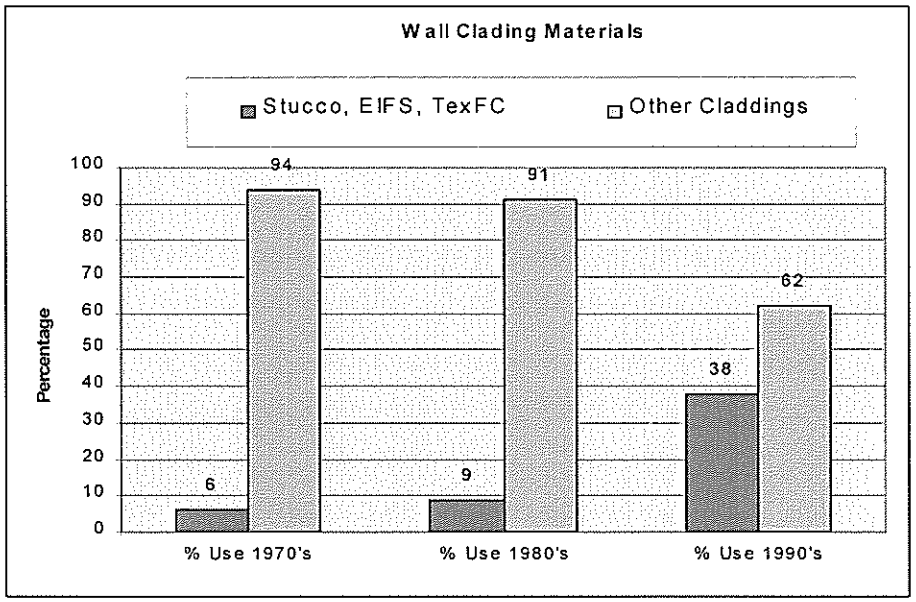

Figure 2.01 Material Use Comparisons 1970-2000

(Murphy, C. et al, Fig3.5)

The Auckland House cladding survey (Murphy, C et al) recognises an increased frequency of use for traditional stucco, EIFS and Textured Fibre Cement Sheeting in the 1990's.

Initial Failure Comparisons

The initial investigation of stucco failures in context to alternative wall systems such as weatherboards and EIFS were based on key word coincidences. To provide a comparative base, the total number of keyword issues recorded against stucco are three times greater than the keyword issues associated with weatherboards, and six times greater than those associated with EIFS. These ratios apply to a high

proportion of the building components which include flashings, windows, roofs and handrails. (Bassett 2001, Draft)

This is alarming as the consistently higher use of 'other' claddings over the years still does not provide greater numbers of failures than the limited use of stucco, EIFS and Textured fibre cement board over the same period.

Requirement for this study

The information currently available in the Branz database does not consider the reasons for failure with regard to actual case studies, rather it deals with observations based on occurrence and does not highlight the actual common failure mechanism or mechanisms. In order to solve, or at least minimise the resultant weathertightness issues as a consequence of stucco failure, the reasons for failure need to be identified and addressed.

3. The Investigation

This chapter will provide the premise to the investigation, give details in regard of the method used and its application and will profile the grouping of issues and the resulting e-matrix.

Hypothesis

Poor workmanship and a lack of attention to the detailing, installation and application of the cladding and its components are the primary causes of weathertightness failure in stucco cladding systems.

Research Method

The BRANZ Site Visit Database (BRANZ dBase 1994-2001) will be used as the source of data to explore stucco related weathertightness building failures. It is recognised that the database is likely to underestimate the extent of the problem, as it is comprised from site inspections and a small number of pre-purchase inspections. The site visit records should provide a reliable understanding of the relative occurrence of the problems. The method used to assemble the data in order to assess it will be by creating an electronic matrix (e-matrix). This method was perceived as the most efficient way to identify problematic areas of the current stucco cladding practice and allowed graphical representation to be generated and further interpreted.

Application of method

The database was used initially to identify the list of case studies to be investigated based on the key word search. The result of this search produces a list of case studies which are directly related to stucco and weathertightness. The key words used in the search were: *stucco & water penetration & weather penetration & leakage & leaks*. This search generated a list of 196 specifically related site reports

from which greater in-depth investigation could be carried out. At this point the database was utilized to its full extent. The next step in the investigation was to individually take each report and identify the key issues/ factors/problems associated with them and record these. From the recorded documentation, each issue/factor/problem was transferred onto the e-matrix. The e-matrix is used to coordinate the data and allow it to be arranged in a way to assist in the investigation of the hypothesis.

Development of the e-matrix (spreadsheet)

As a result of processing multiple reports, the e-matrix developed in such a way that the vertical axis comprised of categorised defects, while the horizontal axis contained the observations affecting each categorised group. These horizontal labels developed to be multi purpose and often provided a link to more than one categorised defect. Example: A lack of control joints were observed
This would be logged at the intersection of control joints (Vertical Axis) and lack of (horizontal Axis). A preliminary example of the e-matrix is provided in Figure 3.01.

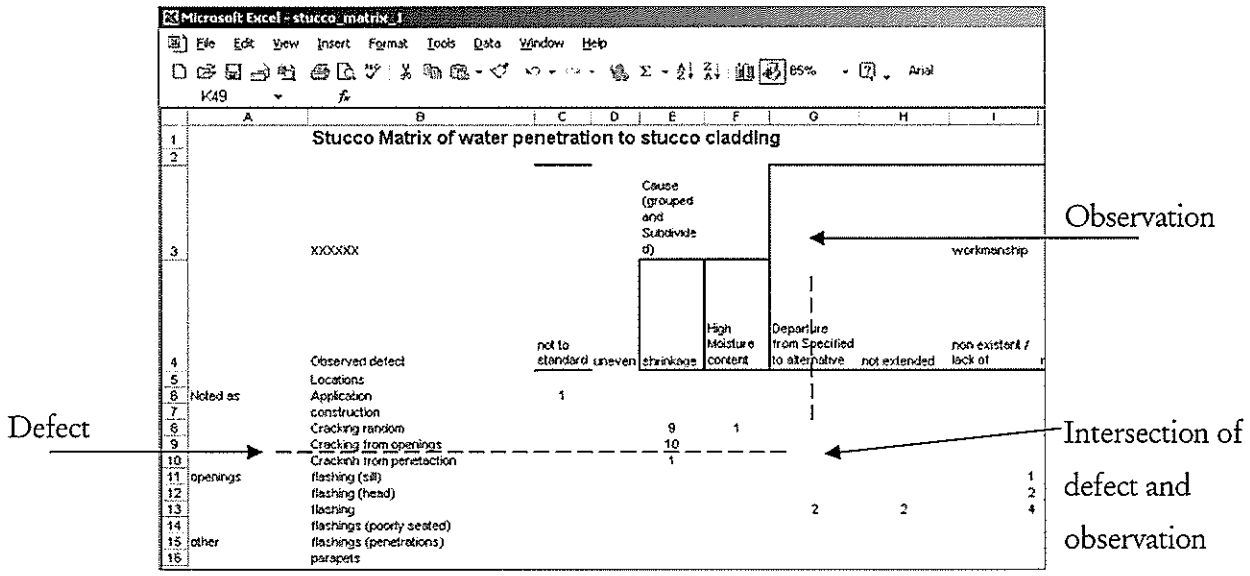

Figure 3.01 Preliminary example of e-matrix

Grouping Development

The development of the e-matrix relied on a certain level of interpretation in respect to generating axis titles and groupings. The majority of the observed defects were straight forward, easily identified and stated clearly in the reports. Some were specific, while others were less specific in regards to the summary comments.

Example one: Flashing not extended, this has being recorded as *Flashings (unspecified in report)* (Vertical Axis) and *not extended* (Horizontal Axis).

Example two: Sill flashing not extended past the edge of the window as required. Where as this would of being recorded as *Flashings (sill)* (Vertical Axis) and *not extended* (Horizontal Axis)

Each title of the horizontal axis has been derived from comments made in the reports. A level of consistency was found in respect to some descriptions of defects and failures. Consistent words used for example: inadequate (insufficient or unsatisfactory in quantity or quality), not extended... etc while other observation titles were derived from larger descriptions. An example of this is a report, which may say: The plaster has been taken down to the ground. The observation title has been specified as Plaster Contact (Horizontal Axis) and would be recorded against the Contact Point – Ground (Vertical Axis).

The vertical axis, which shows the defects in a categorised manner, has been grouped as the e-matrix progressively developed. These are essentially grouped as issues of the stucco cladding system. Each issue has a set sub- issues associated, which assist in their composition. For a list of the overall issues and sub-issues refer to Appendix A: Issues and Sub-issues.

This matrix developed as all 196 site reports were analysed, to the point where the final product could be quantified and trends investigated. A small number (approximately 2%) of reports were unable to be investigated as a result of being signed out for use by Branz staff. The number of unavailable reports did not hinder

the development of trends for stucco related weathertightness failures. A portion of the completed e-matrix is provided in Figure 3.02, for the completed e-matrix, refer to Appendix C: e-Matrix.

Microsoft Excel - stucco_matrix_11

File Edit View Insert Format Tools Data Window Help

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Stucco Matrix: Weather tightness of stucco cladding systems

Issue	Sub-issue	Departure from Specified to alternative / different from design	Inadequate Detailing	Inadequate Design	Not fitted to manufactures Specifications	Fixings through plaster	Shrinkage/ movement	Non existent / lack of	Mix	application conducted in unsuitable conditions (non-shade)	Discol
Affected Faces	Orientation										
Cracking	Cracking random						57				
	Cracking from openings						24				
	Cracking from penetration						3				
	Cracking (wall junctions)						3				
Flashings	Flashings (unspecified in report)	4		3				16			
	Flashing (sill)							23			
	Flashing (head)							18			
	Flashing (jamb)							2			
	Flashings (poorly seated)										
	Flashings (penetrations)	1									
	Flashing (parapets / capping)		1								
Backing	Construction	6	2								
	Reinforcing Mesh	4									
	Fyreline as backing										
	Sub sheathing support										
	Building Paper	1									
	Cement Reinforcing sheet				1						
	Backing support at wrong spacing	1									
	Joints between panels										
	Specified EIFS, used Stucco	1									
Surface	Surface sealant (paint)										1
	plaster thickness										
	Control joints (Between same materials)							40			
	Construction joints (over two different materials)							8			
	Plaster surface									1	
	Drip edge							4			
	Sealant beads / fillets							4			
	Protection from eaves							5			
	Horizontal surface slope							18			
	Provision for drainage behind cladding							11			
	Provision of weep/breather holes for drainage							3			
Mix	Aeration								4		
	Splitting/swelling								3		
	Incorrect design for application								1		
	Soft Bond Coat								6		
	Number of coats										
	Excessive water/cement ratio								1		
	Overworked								1		
	Fine sand / water quantity								5		
	Marine sand used								2		
	Protection from sun										
	Curing process										
	Delamination								7		

Figure 3.02 Portion of completed stucco & weathertightness e-matrix

4. The results

The results of the investigation into the defects associated with stucco cladding and weathertightness have meant that the specific issues contributing to its failure can be identified. These issues are compiled from a specific set of identified sub-issues. This chapter will provide a means of viewing the results generated from the e-matrix. An overall identification of the main issues will be provided, from which further investigation into the sub-issues will be carried out. Each sub-issue will be graphically represented, discussed to provide a specific background and analysis and concluded with preliminary conclusions.

Analysis of results

Main Issues

Figure 4.01 indicates the number of stucco issues related to weathertightness derived from the e-matrix.

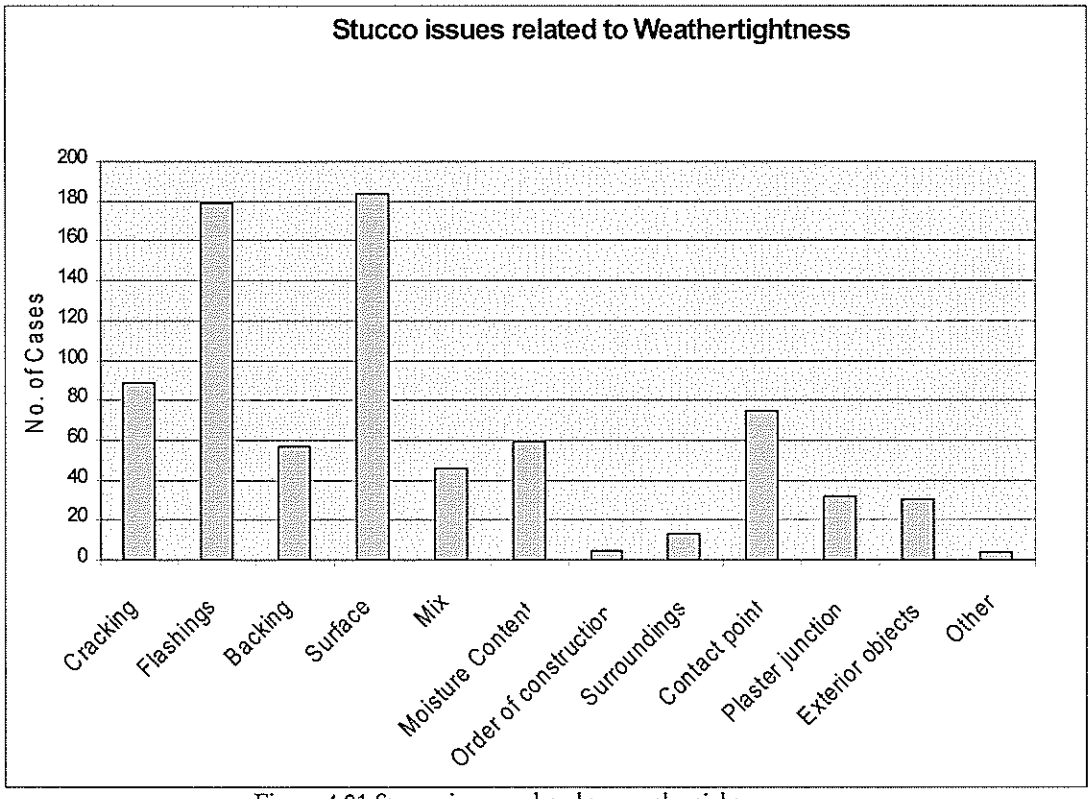

Figure 4.01 Stucco issues related to weathertightness

The graphic presentation allows a quick and easy way of assessing where the most predominant issues of stucco cladding failure are associated. From Figure 4.01 above it can identified that the area of most concern is that of the surface. The following table, ranked from most frequent to least, will assist in providing a summary of issues.

Issue	No. of Issues	% of Total Issues
Surface	184	24%
Flashings	179	23%
Cracking	89	12%
Contact point	75	10%
Moisture Content	59	8%
Backing	57	7%
Mix	46	6%
Plaster junction	32	4%
Exterior objects	30	4%
Surroundings	13	2%
Order of construction	5	1%
Other	4	1%

Table 4.02 Issue Percentage Summary

Table 4.02 indicates that nearly half of all the issues noted in respect to stucco cladding failure are categorised as surface failures and flashing issues. The failures that make up the other half of all issues recorded range from cracking, backing and mix to issues with regard to the order of construction.

The following information provides a greater level of detail as to the actual failures associated to each of the main issues indicated above.

Sub-issues

Surface

Figure 4.03 indicates the number of site visit cases which identify areas of failure in relation to the cladding surface.

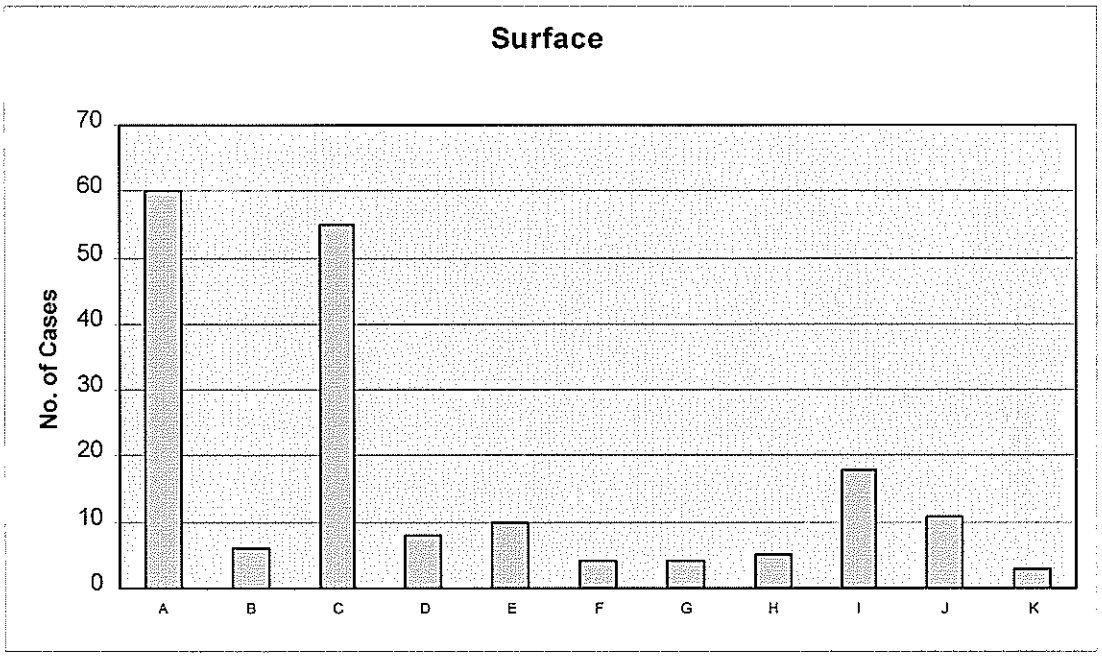

Figure 4.03 Surface breakdown

Legend

A	Surface sealant (paint)
B	Plaster thickness
C	Control joints (Between same materials)
D	Construction joints (over two different materials)
E	Plaster surface
F	Drip edge
G	Sealant beads / fillets
H	Protection from eaves
I	Horizontal surface slope
J	Provision for drainage behind cladding
K	Provision of weep/breather holes for drainage

General

The exterior surface of a stucco cladding system is the first point of resistance to weather penetration. Its failure can lead to greater effects on underlying layers and further deterioration of materials.

Discussion

A high proportion of the issues associated to Surface are from problems to do with surface sealant (paint). Major factors reported are the discolouration, staining and generally inadequate application of the paint. Other factors reported with less occurrences where related to the bubbling, blistering, peeling and the chalky/powdery nature of the surface.

Control joints, which are essential to provide adequate movement to occur in the body of a single material where reported on a number of occurrences (40) as being non-existing and lacking, while a further 14 reports noted that the current control joints provided were inadequate. The reports did not expand on their inadequacy but it is suspected that a poor depth of joint, or the spacing between the joints provided is too great.

The provision for an appropriate slope to a horizontal surface was another area of concern. The reports indicated that in many cases no slope had been achieved at all, therefore allowing the settling of water. This was a concern as water settling on this surface was likely to be absorbed due to the porous nature of stucco cladding and through fine surface cracks.

The provision for drainage behind the stucco cladding was also observed as being an issue, but one report acknowledged that the provision for drainage is rare in the current state of stucco practice. This conclusion was drawn from an observation made of a number of houses in close proximity to the one in which a site report was being conducted.

A major issue relating to the plaster surface was that of discoloration. Again, the reason for this was not expressed but may be as a result of poor mix control in respect to quantities or content.

Construction joints are those joints, which are required when the cladding application passes over two different underlying surface types. It has been indicated that in some cases this provision has not been allowed for and as a result a failure has occurred. A reason for this may be due to the variation of each underlying material having different characteristics. (thermal, porosity etc)

The thickness of the plaster application is an issue in two aspects of the cladding application. Firstly, when applied over a non-rigid backing with inadequate support, a variation in thickness can result in order to achieve an even surface. Secondly, is the issue of the minimum thickness of plaster applied in order to provide an appropriate cover to the reinforcing mesh and other underlying objects.

The protection from eaves is an issue that is only briefly highlighted here but is suspected to increase in the future as a result of the new trend towards cleaner lines and maximised footprint areas.

Other issues identified from the reports, but with a minimal number of occurrences is the lack of drip edges and sealant beads or fillets.

Tentative Conclusion

The issues raised in the surface grouping indicate some issues associated with the applied sealant component. It is unsure whether this is an application problem or the use of an incorrect product. Other failures may stem from poor workmanship, design and a general development of modern styles.

Flashings

Figure 4.04 indicates the number of site visit cases which identify issues in relation to flashings.

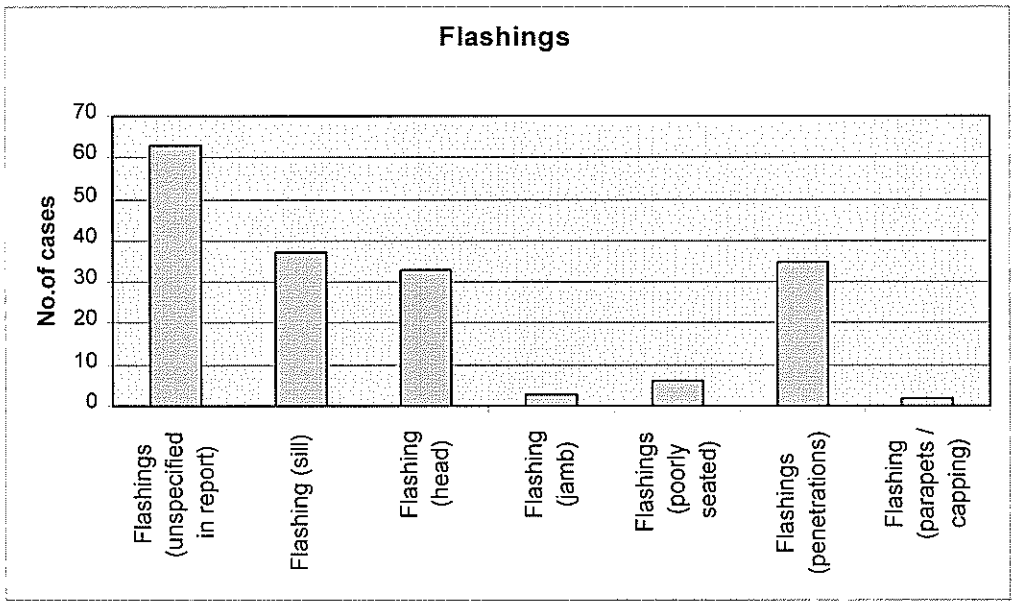

Figure 4.04 Flashing issues

General

Flashings are an important part of any building and cladding system, but are of especially high importance when utilized in cooperation with stucco cladding systems.

A required awareness of flashings, not only to the larger openings but also to the smaller penetrations (meter boxes, penetrating pipes or similar) is essential.

Discussion

Many of the reports documented flashings in the general sense, while a limited number specified which flashing, or at least its intended position, was failing.

All reports, whether general or specific tended to provide similar observations. Of the reports, which specified issues with flashings, almost one third of them were due to the flashings being non-existent. Another third are reported as being inadequate.

Other issues raised related to what can be attributed to as workmanship issues, where the flashings had been plastered over, poorly lapped, no upturn provided, or in some cases not extended past the extremity of the element being flashed.

A limited number of reports, typically those that had been taken to a higher level of investigation, provided information that indicated that the failure was due to a change from what was originally specified to an alternative means/method of flashing, while a limited number acknowledged that the failure was a direct result of poor design.

A number or cases involving flashings around penetrations indicated that they were inadequate and in many cases poorly sealed.

Preliminary Conclusion

Flashings, even if designed specifically for an application are ultimately influenced by the workmanship of the installer. It's this factor that is believed to be a major cause of the issues identified, resulting in failure.

Cracking

Figure 4.05 indicates the number of site visit cases which identify cracking to areas of cladding.

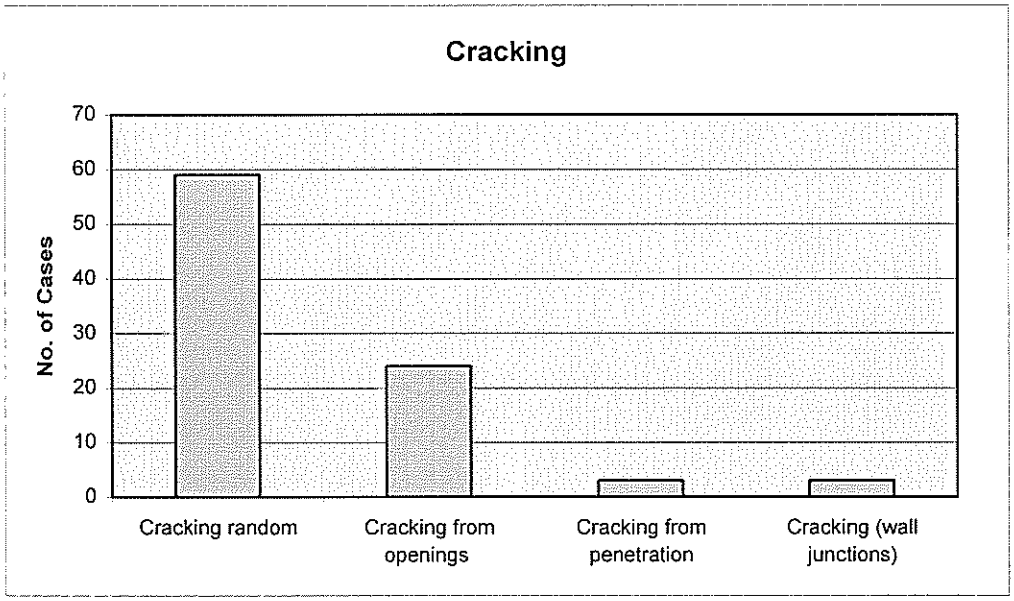

Figure 4.05 Cracking issues

General

Cracking can be not only an unsightly problem, but also one that can lead to severe damage if left unattended. A link may be able to be attributed to the control joints, mix, reinforcing mesh as these are all factors, which if not complete properly can contribute to cracking.

Discussion

All types of cracking were generally assessed as resulting from shrinkage or movement. The specific causes of each type of cracking were rarely discussed but the general response of the reports indicated that control joints were major contributors to the random cracking. Cracking from openings and penetrations is believed to be caused primarily by insufficient additional reinforcing at the corners.

Preliminary Conclusion

The mix type and the quantities of components from which it is manufactured are critical and have an influence on the shrinkage of the stucco body. The requirement for greater attention to be paid to adequately spaced control and construction joints is also an area, which appears to need addressing.

Contact Point

Figure 4.06 indicates the number of site visit cases where contact between the cladding and another component has occurred.

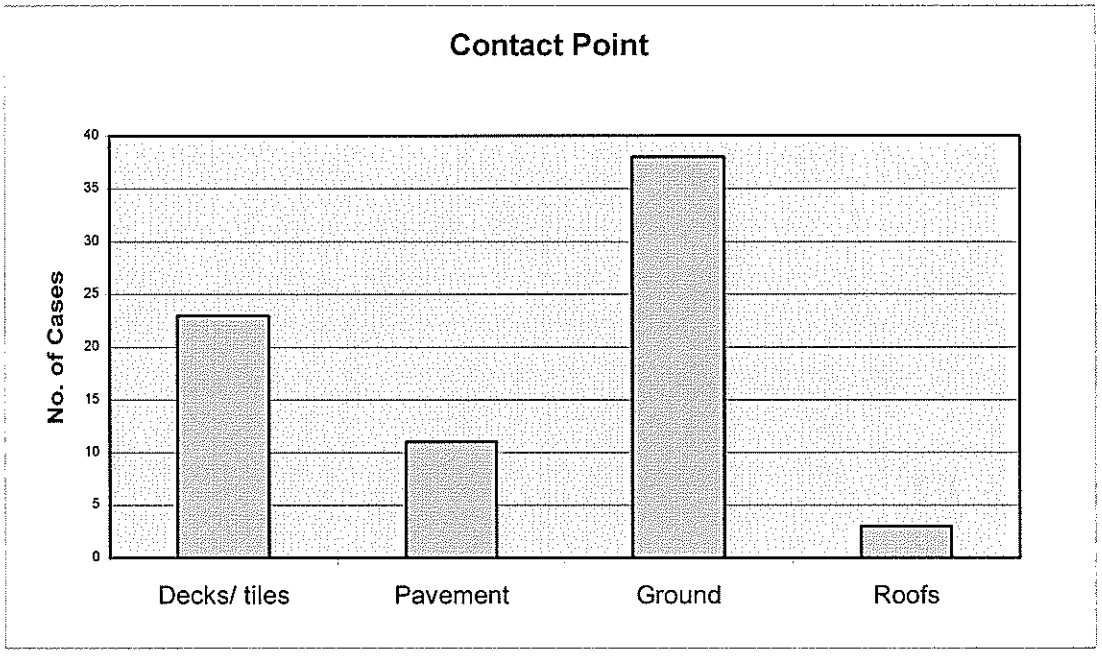

Figure 4.06 Contact Point issues

General

Under no circumstances should stucco be carried down to ground level, ideally a 100mm gap is to be provided to paving while a 175mm gap is ideally provided to ground[1]. The contact of stucco cladding with the ground can lead to capillary action, causing water to be sucked up.

Discussion

A number of cases highlighted the fact that the stucco cladding had been taken down to an adjoining component/surface. A number of reports indicate issues with contact to ground, decking and paving features. This results in two major issues, firstly the capillary action created by the stucco essentially sucking up the water and

[1] Ten Broeke and Hardie

moisture through its porosity. The second is the inability for moisture, which has found its way into the stucco cladding to drain at the bottom. Both these aspects result in the cladding withholding moisture and overtime causing it to become weak.

Preliminary conclusion

The high number of occurrences associated to the stucco being in contact may be as a result of an increased fashion to have gardens and other aspects of landscaping placed up against the building face. This may be as a result of this work being carried out well after the exterior plastering has been completed.
The number associated with contact to decks and tiles leads a Preliminary conclusion to be drawn that poor workmanship and a lack of attention to design are likely causes. .

Moisture Content

Figure 4.07 indicates the number of site visit cases where high moisture levels to building components are identified.

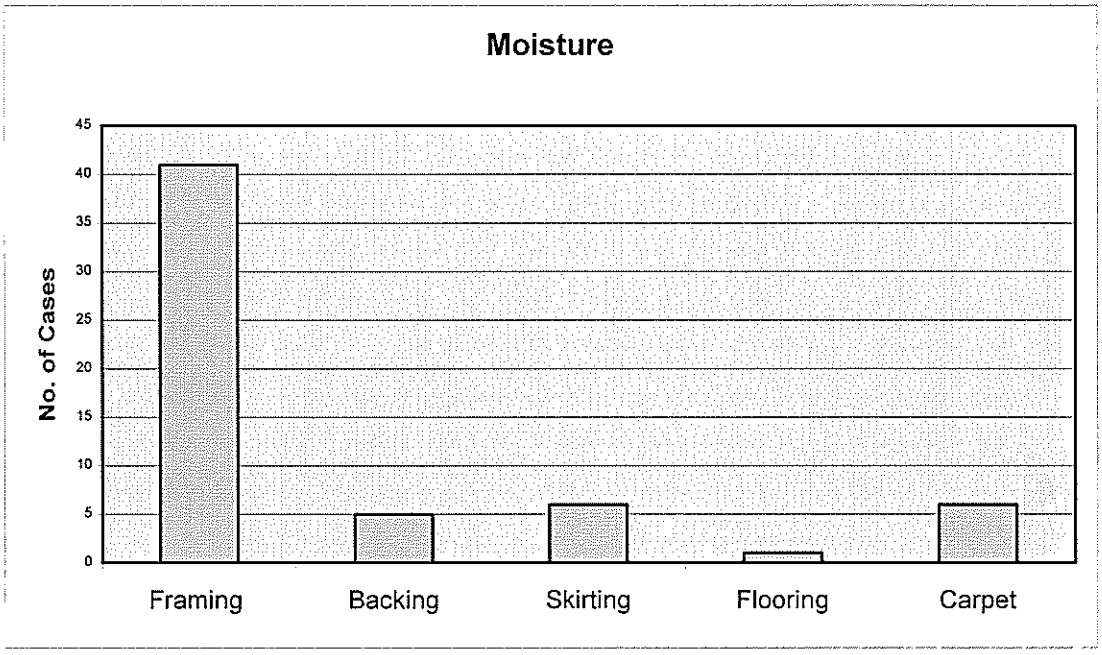

Figure 4.07 Moisture Content

General

Due to the typical nature of construction, the use of lightweight timber framing is a serious concern when it comes to moisture. High moisture levels in timber can have serious implications in respect to dimensional change and also the lifespan of the material. Excessive moisture levels for an extended period may see the result of fungal growth and material deterioration.

Discussion

A majority of the cases indicated extreme measured moisture levels in the wall framing. The moisture levels were measured using probe moisture meters, which could be driven into the framing allowing a relatively unobtrusive test to be conducted. The high moisture levels indicate the possibility of fungal growth,

desecrated insulation and building paper but a majority of the reports did not enter into such radical destructive testing to confirm or deny this.

Preliminary Conclusion

For moisture to get to this point the failure of cladding elements and components has already taken place. The appropriate management of moisture that does enter would drastically reduce the damage to additional components.

Point worth noting

The generalisation of framing moisture makes one wonder that if the framing has high moisture shouldn't the backing also, this may be the case but due to non-destructive testing this may not of being able to be conclusively stated in the reports.

Backing

Figure 4.08 indicates the number of site visit cases where issues in relation to backing are identified.

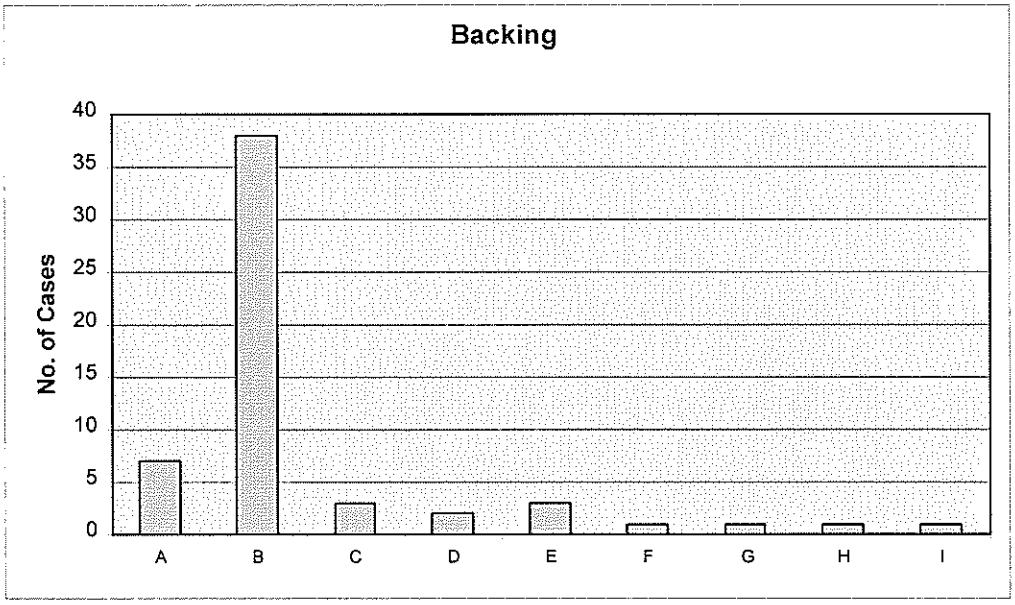

Figure 4.08 Backing issues

Legend

A	Construction
B	Reinforcing Mesh
C	Fyreline as backing
D	Sub sheathing support
E	Building Paper
F	Cement Reinforcing sheet
G	Backing support at wrong spacing
H	Joints between panels
I	Specified EIFS, used Stucco

General

The choice of backing, non-rigid or rigid and the type of reinforcing used can influence the stud and dwang spacings of the lightweight structure to which it is applied. The reinforcing needs to be adequately spaced from the backing to allow the mesh to be embedded into the plaster.

Discussion

The component most reported as been a problem is in relation to the reinforcing mesh. The major issue associated with it relates to the poor positioning of the mesh with a number of cases indicating that it is inadequately positioned at the rear of the applied plaster. Other areas of concern are a small number of cases, which indicate a lack of additional reinforcing around stress points and the corners of openings, and rusting stables, which essentially secure the cladding to the wall. More detailed reports indicate that the mesh used was an alternative shape or size to what was specified.

Very small numbers of reports saw issues raised in relation to the incorrect backing materials used, the backing materials applied over inadequately spaced supports or poor jointing between panels.

Preliminary Conclusion

Many of these failures indicate that sufficient measures by those conducting the task were not undertaken to ensure the basics of stucco practice were followed.

Mix

Figure 4.09 indicates the number of site visit cases where issues are raised in relation to the cladding mix.

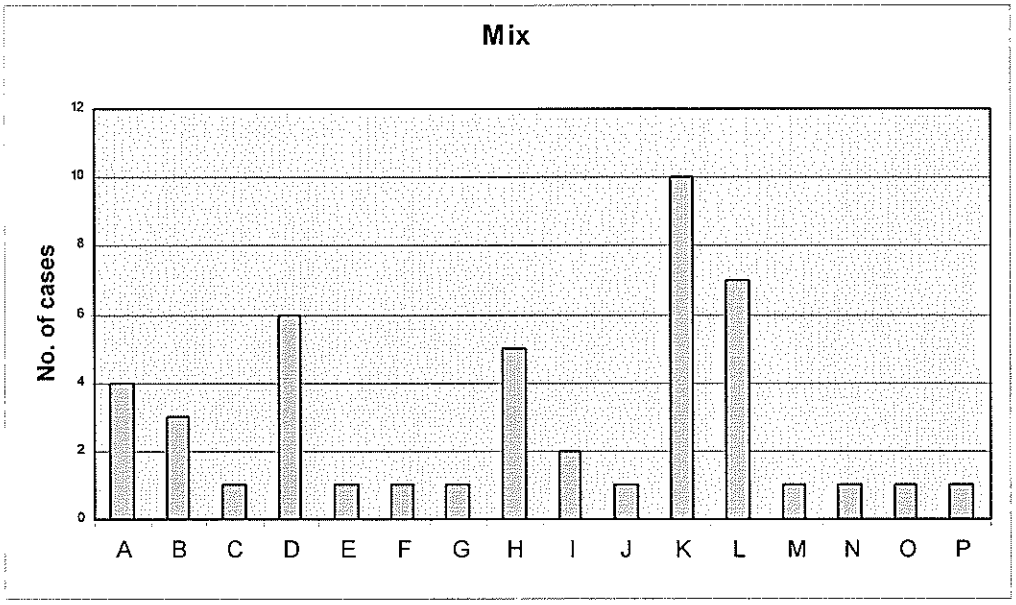

Figure 4.09 Mix issues

Legend

A	Aeration
B	Splitting/swelling
C	Incorrect design for application
D	Soft Bond Coat
E	Number of coats
F	Excessive water/cement ratio
G	Overworked
H	Fine sand / water quantity
I	Marine sand used
J	Protection from sun
K	Curing process
L	Delamination
M	Lack of Hydration
N	Porous
O	Leaking alkalinity
P	Application

General

The mix has a number of variables, which can dramatically affect the performance of the final product. The components from which it is made, the way its applied and cured are critical, but the one factor that cannot be over looked is the importance of following the product manufactures recommendations.

Discussion

The nature of the stucco plaster, as it contains a proportion of cement sees a critical element to its success being the curing process. Approximately one quarter of the cases, which identify aspects in relation to mix, are directly attributed to inadequate curing procedures. This is vital and it seems all too often over looked. The number of cases, which indicate a soft bond coat, can confirm this. The delamination of layers caused by a combination of mix and inadequate keying of the previous layer is unsightly and can cause even greater extents of failure. The actual components that go into a mix are also important, as can be seen by a number of cases that indicate the use of sand that is too fine.

Preliminary Conclusion

An increased awareness of the implications of accurate mix quantities, and the increased ability to adhere to an adequate curing process would assist in the reduction of the cases associated with mix.

Plaster junction

Figure 4.10 indicates the number of site visit cases which identify issues of the plaster junction to other objects.

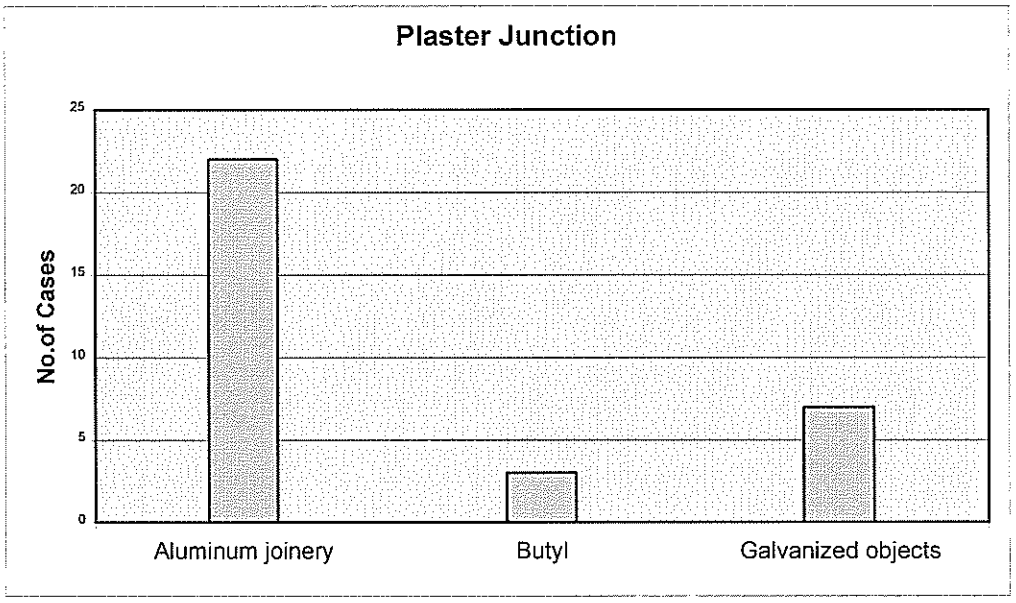

Figure 4.10 Plaster junction issues

General

The junction of plaster to another material is important to prevent leakage but it is also important to ensure the appropriate compatibility of the materials.

Discussion

The junction between the aluminium joinery and the stucco cladding system has in many reports indicated cracking between the two. This again enforces the need to provide adequate flashings around penetrations. Issues related to the plaster junction include being inadequate, poorly sealed or plastered over. The main problem between the junction of plaster and galvanised objects is reported as resultant corrosion. The Portland cement component of a stucco mix affects both aluminium and galvanised materials causing corrosion, therefore it is essential that these materials are protected during the application and curing of the stucco mix.

Preliminary Conclusion

The cause of these types of failures may be as a direct result of poor workmanship. An increased knowledge of the dramatic effects of the stucco mix on other materials, and the way in which the junctions between adjacent materials are dealt with is required.

Exterior objects

Figure 4.11 indicates the number of site visit cases where exterior objects have provided issues to stucco cladding.

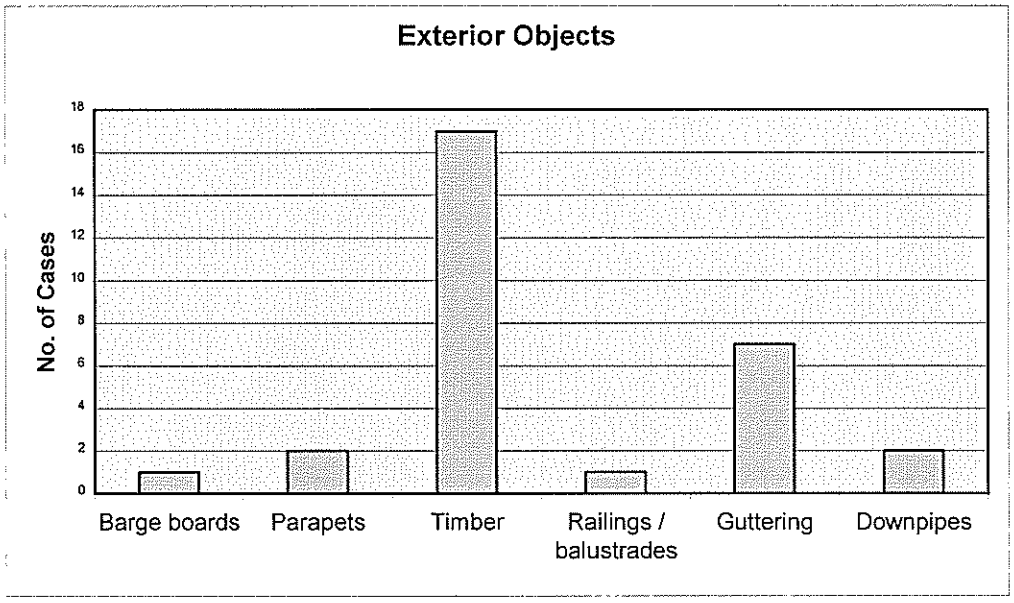

Figure 4.11 Exterior objects

General

For the plaster to work effectively the surface ideally must remain unpunctured and intact. The penetration or embedding of an object through, or into the plaster surface can quickly lead to water and moisture ingress and eventual failure.

Discussion

The majority of concerns raised in relation to exterior objects are the issues raised as a result of timber objects being embedded into the stucco surface. The most reported was specifically timber objects such as pergolas and similar elements, while guttering was also reported as being embedded in the plaster. Other items of lesser concern were raised in relation to the fixings of different objects through the plaster surface. Signs of moisture ingress from these penetrations were reported.

Preliminary Conclusion

Greater attention needs to be paid to the items either penetrating or being placed in close proximity to that of the finished plaster system. Workmanship may be the primary cause, with a requirement to educate the industry in order to express the dramatic effects such small penetrations or slightly embedded objects can cause.

Surroundings

Figure 4.12 indicates the number of site visit cases where issues concerning the surroundings have been identified.

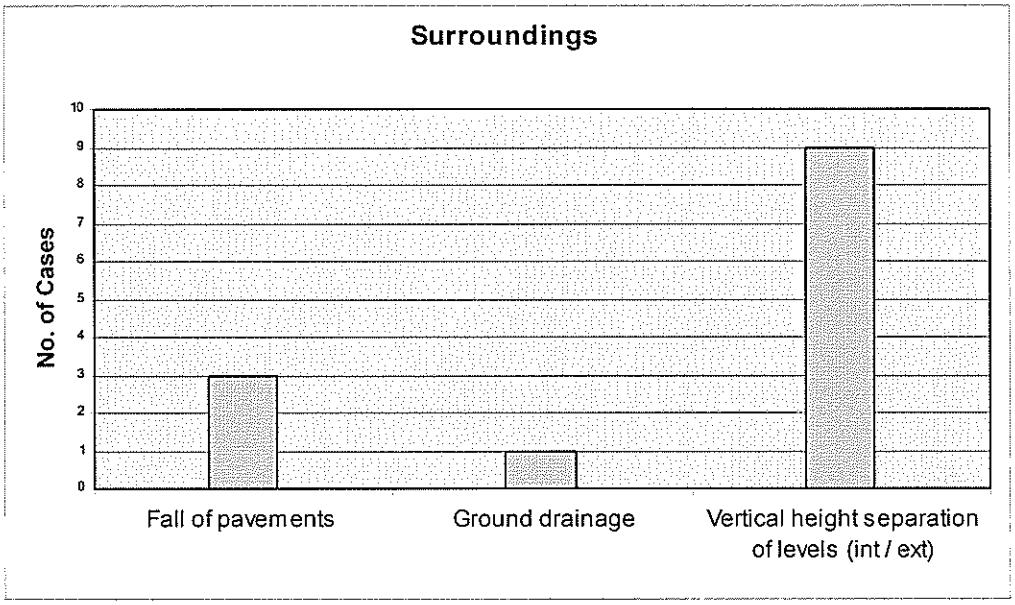

Figure 4.12 Surroundings issues

General

The surroundings in close proximity to a stucco cladding system are very important. They have the ability to cause failure even if the cladding itself has been applied and cared for in an appropriate manner.

Discussion

The main issue raised from the reports is the inadequate vertical height separation between the interior and exterior levels. This results in the stucco cladding not being continued down far enough past the bottom plate. Other aspects are the poor attention paid in relation to a correct fall to pavements near or in contact with the cladding. One case also highlighted poor ground drainage as being a factor.

Preliminary Conclusion

The largest issue discovered here is the lack of vertical separation between levels. Again, few cases actually investigate the reason for this but it suggests it could be a

design issue, driven by the current trends of the modern styling. The remainder of the problems are regarded as workmanship type issues with a lack of attention being paid to the final product.

Order of Construction

Figure 4.13 indicates the number of site visit cases where the order of construction has resulted in issues.

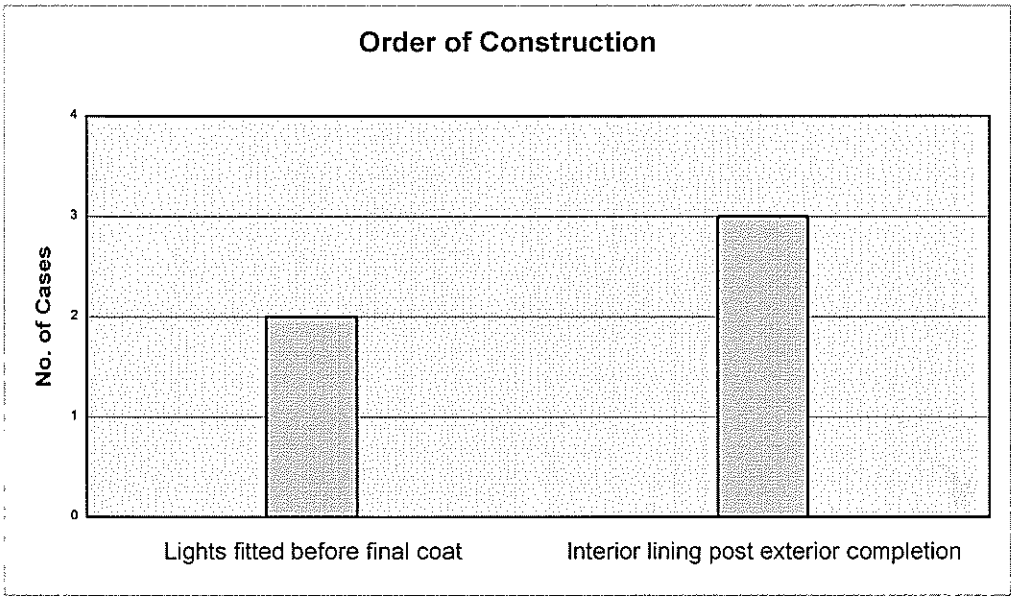

Figure 4.13 Order of construction

General

The avoidance of vibration after the completion of the final plaster coat is essential and a general common sense order of construction is expected from trades people.

Discussion

There were two main examples brought to light, one concerning the fitting of light fixtures prior to the final coat. This resulted in the final coat not providing full coverage of the surface and poorly finished edges around the fixture. The other issue raised was that of the plaster exterior finish being completed before the internal linings were complete. The vibrations caused during their installation were enough to cause substantial cracking to the exterior plaster.

Preliminary Conclusion

Poor workmanship or practice procedures are perceived as the direct cause of these problems.

Summary

The weathertightness issues directly associated with stucco cladding have been investigated and categorised. The high occurrence of the defects documented from the site visit reports provided a means of isolating the issues associated with the current stucco practice. From the discussions and Preliminary conclusions in regard to each issue and sub-issue, three factors emerge as being responsible for the majority of stucco weathertight failures:

- Design
- Detailing
- Workmanship

These factors are derived from the preliminary conclusions generated previously for each issue. A majority of the reports did not enter into sufficient detail to provide conclusive evidence of what or who was to blame, but rather indicated the issues contributing to the failure. It is from these contributing issues that the factors above are derived. Workmanship is the key factor to providing a cladding system with a low probability of failure.

5. Conclusions & Recommendations

This chapter will provide conclusions from the investigation process. Based on these, recommendations will be made which will identify measures to limit the probability of failure.

A stucco cladding system has the ability to provide a sound, durable, and water resistant surface when applied in a manner that follows good practice guides and industry documentation. The unforgiving nature of a stucco cladding system means each detail and step involved in its application is vital to ensure its successful performance.

The investigation into the weathertightness of stucco cladding systems provided preliminary conclusions for each of the issues identified. These essentially determined three factors to which stucco failure is attributed.

- Design
- Detailing
- Workmanship

Design, Detailing & Workmanship

Design

Innovative styling and modern designs have resulted in the increased use of designer shapes and curves which are clad using stucco, as opposed to conventional sheet cladding systems. Maximisation of the building footprint and a modern appearance is achieved by the removal of overhangs, resulting in the greater exposure of a wall and its components to the natural elements. Innovation should not be completely forgone, but the basic weathertight principles need to be acknowledged.

Detailing

Designs which 'push the boundaries' need to ensure the required weathertightness is not compromised. Detailing to standard openings and penetrations must be carried out to an adequate level. For unconventional designs, specific detailing to the relevant areas must be addressed to minimise failure. Detailing carried out in accordance with industry documentation and recommendations will ensure a successful cladding system. However, this success is ultimately dependent on workmanship carried out on site.

Workmanship

High standards of skill and a sufficient knowledge base of the industry are essential. Up-skilling is required in order to keep up with constantly developing materials, methods and techniques. Standards of workmanship are often of inadequate, resulting in extensive failures to stucco cladding systems.

Recommendations

The recommendations which have arisen from this investigation are presented in the following text in order of priority based on the frequency of occurrence. In addressing these major issues, reference is made to the relevant sections of the Ten Broeke & Hardie (1996) publication, *Good Stucco Practice* to provide a level of knowledge of how to produce cladding systems with a low probability of failure.

- Ensure control joints are present, at adequate spacing and occur frequently. These need to be implemented to sufficient layers of the cladding system. Construction joints must be provided where stucco cladding passes over two different types of underlying materials.

Refer to Appendix B for the relevant Branz Good Stucco Practice clause, 3.8 Control joints.

Summary of recommendations

The following are the most frequently occurring issues associated with stucco cladding failure:

- Control joints
- Slope to horizontal surfaces
- Plaster thickness
- Flashings
- Ground clearance
- Reinforcing mesh
- Non-rigid backings
- Correct mix
- Surface preparation
- Curing procedures
- Protection of aluminium joinery and glass
- Order of construction
- Surface sealant*

While it can be recognised that some of the issues raised are related to design and detailing of the building and cladding system, ultimately the trades people who are carrying out the work should only do so if they are confident that the underlying design and detailing will provide a suitable surface to which the stucco cladding can be applied.

Accept and Manage

While the recommendations prior highlight the need for advanced levels of workmanship to be guaranteed, a change in the design strategies may also need to

be introduced if an increased level of workmanship can not guarantee weathertight stucco cladding systems.

The principle behind the advanced design would **accept** that the water or moisture will enter and allow it to be **managed** by allowing a means of escape. It is this principle which is rarely undertaken in New Zealand. The acknowledgement and understanding of this is essential as the use of less traditional (e.g., EIFS) and essentially unproven forms of cladding have become widespread.

Having acknowledged the current stucco downfalls which exist in the industry, steps towards reducing the extent of these failure issues need to be undertaken.

- Greater **education** to the profession and trades people.
- Continual **up-skilling** and advanced training
- Greater **enforcement** of the industry standards would increase the level of performance of stucco claddings.

Additionally, by placing the responsibility of weathertightness failure which occurs during a specified timeframe, on the professionals who carried out its design, detailing and application would also result in the increased standard of workmanship.

6. Future Work

It has been acknowledged that the weathertightness failure of stucco cladding systems is not the only cladding type to herald problems.

Further investigation into the reported alternative cladding systems which are also failing would provide a similar in-depth investigation and ultimately produce recommendations to minimise or ultimately eliminate the extent of failures.

Comparisons can be drawn based on the keyword coincidences linking materials and material systems to building components. (Bassett 2001, Draft)

Initial Comparisons

This section will be used to view stucco failures in context to alternative wall systems such as weatherboards and EIFS based on key word coincidences. To provide a comparative base in regard to how much of a problem stucco cladding systems are in comparison to alternatives, the total number of keyword issues recorded against stucco are three times greater than the keyword issues associated with weatherboards, and six times greater than those associated with EIFS. These ratios apply to a high proportion of the building components which include flashings, windows, roofs and handrails to name a few. (Bassett, Draft)

The reasons for these can be attributed to the greater workmanship and detailing required when dealing with stucco and the less forgiving nature of the cladding. Stucco cladding systems are unable to fundamentally cope with leakage problems brought about by failures in regard to flashings and openings (windows and joinery). Currently, stucco cladding systems are resulting in higher levels of failure, this need not be the case and can be prevented if the application is conducted in a 'good practice' manner.

Stucco cladding requires greater levels of attention, not only to the underlying preparation but also to the actual application and maintenance of the plaster system, and this needs to be acknowledged.

Further investigation into the actual causes of the alternative cladding failure in relation would identify the reasons for their failure and provide a means of in-depth comparison between them.

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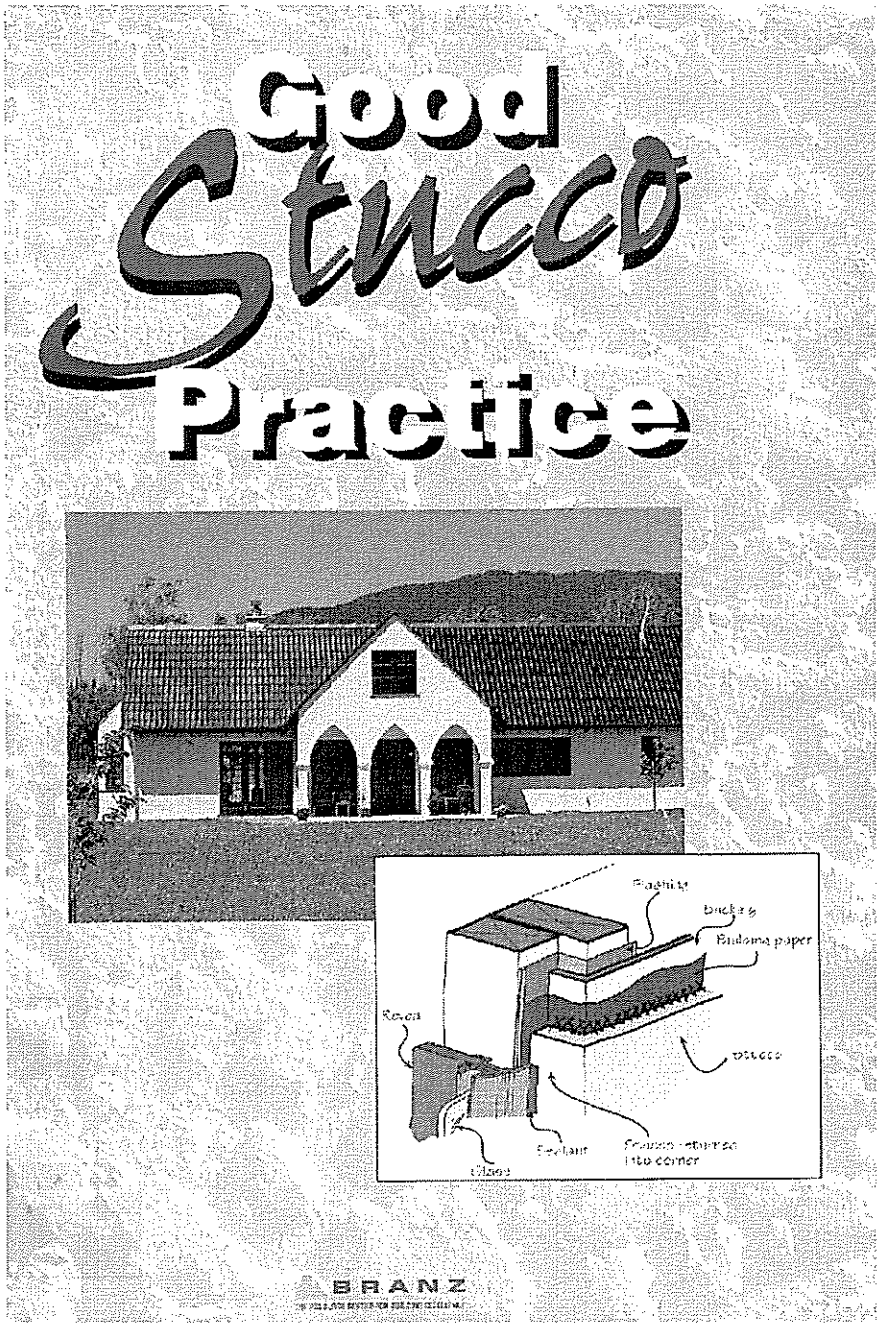
8. Appendix A: Issues and Sub-issues

Issues	Sub-Issues	Individual	Summary
Affected faces	Orientation	27	27
Cracking	Cracking random	59	89
	Cracking from openings	24	
	Cracking from penetration	3	
	Cracking (wall junctions)	3	
Flashings	Flashings (unspecified in report)	63	179
	Flashing (sill)	37	
	Flashing (head)	33	
	Flashing (jamb)	3	
	Flashings (poorly seated)	6	
	Flashings (penetrations)	35	
	Flashing (parapets / capping)	2	
Backing	Construction	7	54
	Reinforcing Mesh	38	
	Fyreline as backing	3	
	Sub sheathing support	2	
	Cement Reinforcing sheet	1	
	Backing support at wrong spacing	1	
	Joints between panels	1	
	Specified EIFS, used Stucco	1	
Surface	Surface sealant (paint)	60	171
	plaster thickness	6	
	Control joints (Between same materials)	55	
	Construction joints (over two different materials)	8	
	Plaster plane	10	
	Horizontal surface slope	18	
	Provision for drainage behind cladding	11	
	Provision of weep/breather holes for drainage	3	
Mix	Aeration	4	46
	Splitting/swelling	3	
	Incorrect design for application	1	
	Soft Bond Coat	6	
	Number of coats	1	
	Excessive water/cement ratio	1	
	Overworked	1	
	Fine sand / water quantity	5	
	Marine sand used	2	

	Protection from sun	1	
	Curing process	10	
	Delamination	7	
	Lack of Hydration	1	
	Porous	1	
	Leaking alkalinity	1	
	Application	1	
Moisture Content	Framing	41	59
	Backing	5	
	Skirting	6	
	Flooring	1	
	Carpet	6	
Order of construction	Lights fitted before final coat	2	5
	Interior lining post exterior completion	3	
Surroundings	Fall of pavements	3	17
	Building Paper	3	
	ventilation	1	
	Ground drainage	1	
	Vertical height separation of levels (int / ext)	9	
Contact point	Deck/ tiles	23	75
	Pavement	11	
	Ground	38	
	Roofs	3	
Plaster junction	Aluminium joinery	22	32
	Butyl	3	
	Galvanized objects	7	
Exterior objects	Drip edge	4	43
	Barge boards	1	
	Parapets	2	
	Timber	17	
	Railings / balustrades	1	
	Guttering	7	
	Down pipes	2	
	Sealant beads / fillets	4	
	Protection from eaves	5	
Other	Other objects (wall and column)	1	5
	Interior	1	
	Non- compliance	3	



Ten Brooke, J and Hardie, G; *Good Stucco Practice*, BRANZ, 1996

DESIGNING FOR STUCCO

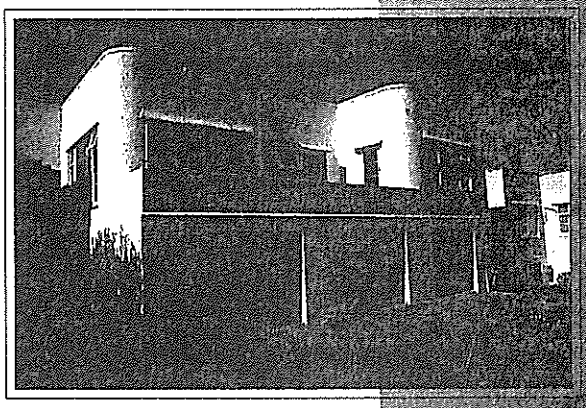
3.0

3.1 General

3.1.1 The two essential criteria for designing stucco-clad buildings are:

- Restriction of cracking resulting from movement in the building or shrinkage of the plaster, and
- Control of moisture to prevent damage to the structure or building interior.

3.1.2 Moisture control should be tackled on two fronts - firstly, by trying to eliminate moisture entry and secondly, by providing for the disposal of any moisture which does enter the cladding, in a way that causes no damage.



Older stucco style with coved projections prevents moisture entry around windows.

3.1.3 BRANZ recommends

It is the designer's role to determine what details are to be used, where control joints are to be located and the desired surface texture. The designer may consult with the plasterer, but should not expect the plasterer to make design decisions.

3.2 Foundations

3.2.1 Traditionally, foundations for stucco clad buildings have been concrete perimeter foundation walls. In more recent times, concrete masonry wall and concrete floor slab-on-ground as foundations have been widely used. It is assumed that these foundation systems have been used to reduce the risk of cracking from uneven settlement when compared with piled foundations. Another possible reason is the support required for the relatively heavy wall cladding (at 50 kg / m^2), although the width of the footing is kept the same as for lighter claddings such as weatherboards.

stiff and there are fewer opportunities for fixing reinforcing mesh to the timber framing.

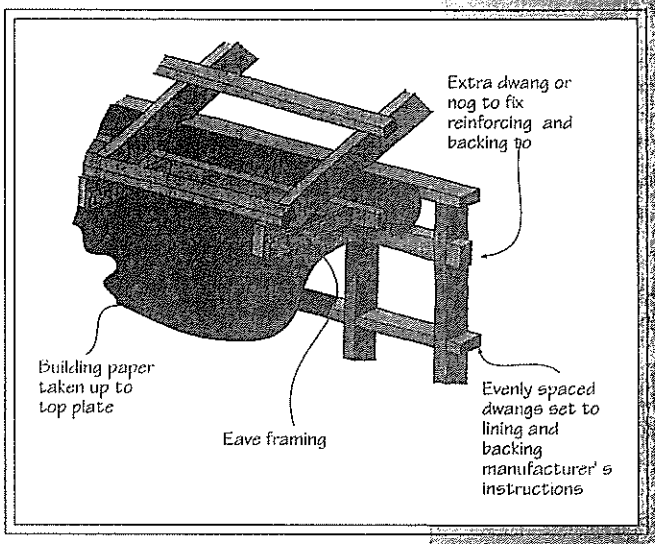


Figure 2. Dwangs required under eaves.

3.5.3 BRANZ recommends

For exterior walls clad with stucco, 400 mm stud spacings and (for a 2.4 m studheight) three rows of dwangs with the top one located immediately below eaves level to provide top fixing (see Fig.2). Wider stud spacings are acceptable for rigid backings where specifically permitted by the manufacturer's literature.

3.5.4 The recommended 400 mm stud spacing is based largely on the strong consensus among experienced plasterers, and the fact that smaller spacings reduce the amount of likely backing distortion and variability in plaster thickness which could lead to failure.

3.5.5 Wall framing must also take into consideration the requirements of the backing material. Some materials, such as "Triple S", require dwangs to be spaced at no more than 600 mm centres. All wall framing must be well braced to reduce movement under racking loads.

3.5.6. Another problem identified by plasterers is that tall wall framing, such as occurs on gable walls with skillion roofs, is often of smaller cross section than specified in NZS 3604, producing a frame which is too flexible. With trussed roofs the infill truss to form the gable commonly has 50x50 mm vertical members at approx 400 mm centres between bottom chord and rafters (top chord). On a steep roof, these vertical members can often span over 3 m and there are usually no dwangs in the trusses.

materials are stainless steel self-drilling screws. Hot-dipped galvanised self-drilling screws would be suitable if introduced by manufacturers.

3.7 Flashings, Trim and Metal Components

3.7.1 The provision of proper flashings around openings in the cladding is essential, with windows having both head and sill flashings (see Figs. 4 and 5). Head flashings must project horizontally at least 30 mm beyond each side of the opening to ensure that water dispersed from each end does not enter any possible gap between the cladding and window or door jamb. Examples of suitable side flashings to openings are shown in Figs. 6, 7, 8 and 9.

3.7.2 All metal components used in stucco work must be made of materials compatible with wet plaster, easy to form to the required shape, and with at least the same durability as the building elements to which they are fixed. Materials which can be used include stainless steel, powder-coated aluminium, powder-coated hot dipped galvanised steel and hot-dipped galvanised steel. The weight of the galvanised coating should be no less than 400 g / m^2 (Z400). P.V.C. may be used for control joint mouldings and corners. **Zincalume-coated steel is not suitable as it deteriorates in contact with Portland cement.**

3.7.3 The extra cost of protecting components is a good investment as replacement is usually very difficult and expensive.

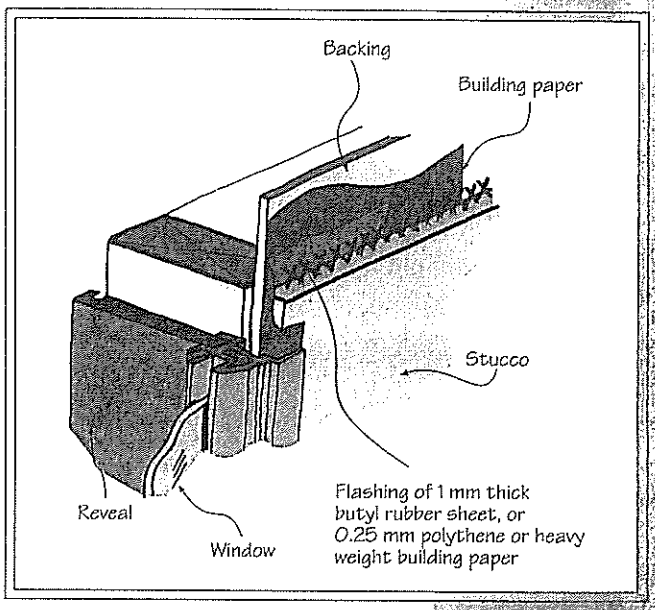


Figure 6. Concealed flexible sheet side flashing.

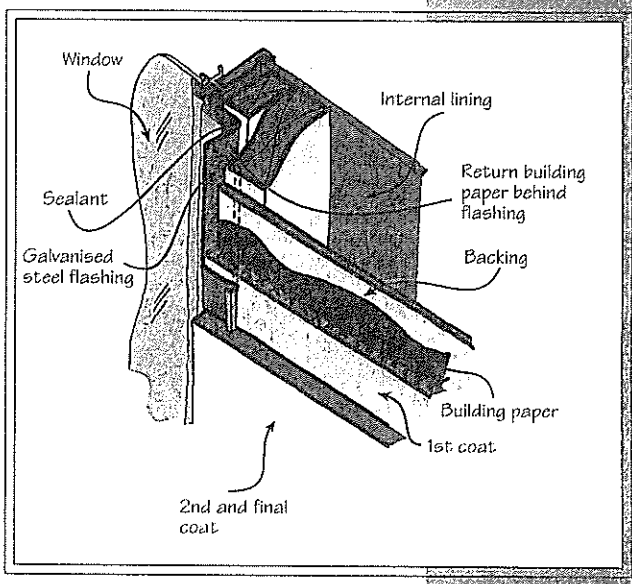


Figure 7. Recessed window with flashing embedded in second coat.

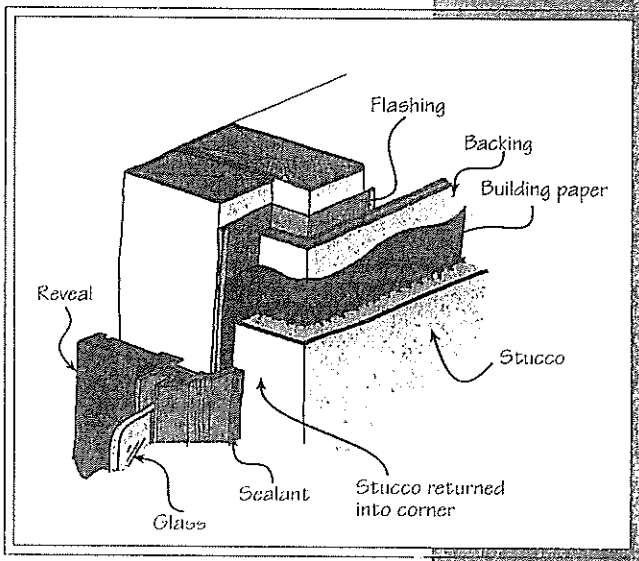


Figure 8. Recessed window with concealed back flashing.

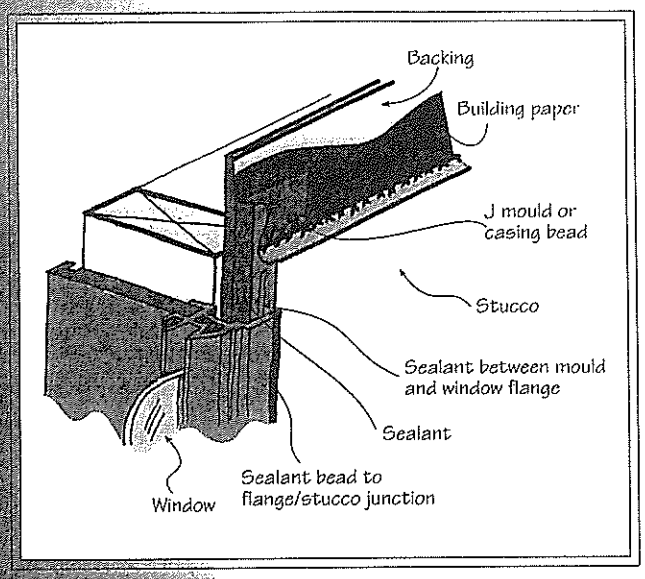


Figure 9. J-mould side flashing.

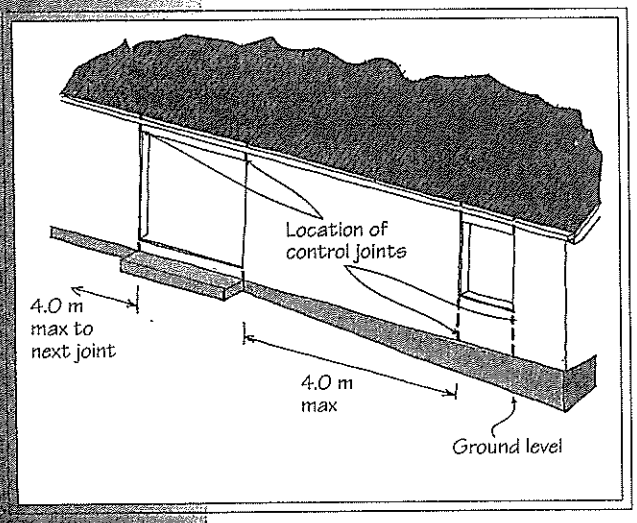


Figure 10. Control joint location and spacing.

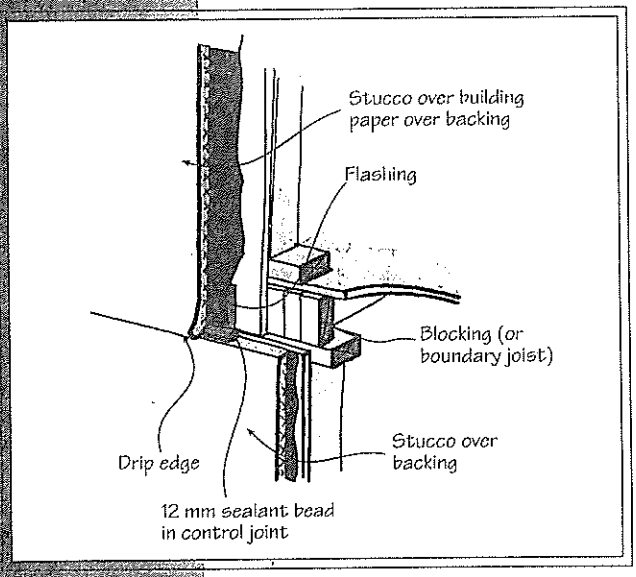


Figure 11. Horizontal joint at storey height.

3.8 Control Joints

3.8.1 The sensible provision of control joints is good insurance against uncontrolled unsightly cracking. All materials having cement as a binder will shrink as they set and dry out. Drying shrinkage will continue for some time after setting. The amount of shrinkage can be limited by good mix design, but it cannot be eliminated altogether. This shrinkage will create stresses in the plaster that can be partly resisted by reinforcement, but the result is usually many very fine invisible cracks. However, when walls are long or weaknesses are created by openings, larger cracks are likely to occur. The size and direction of these cracks is usually not known beforehand, leading to random cracking, unacceptable appearance and water penetration.

3.8.2 A control joint is a deliberately induced line of weakness in the plaster which predetermines the position, and allows effective waterproofing, of larger cracks should they occur. The location is chosen to avoid detracting from the appearance. Control joints can also accommodate thermal stresses.

3.8.3 Vertical control joints should be formed above and below the sides of openings such as doors and windows, and at maximum 4 m intervals (see Fig. 10). In some parts of the country where the temperature range from summer to winter is large, plasterers form joints at 2.5 m spacing between openings.

3.8.4 Horizontal control joints (15 mm wide) should be formed at inter-storey levels at the underside of the floor joists. This is the location at which timber shrinkage movement is most easily accommodated. The joints must be protected against water run-off from above by using a drip edge or bell cast,

3.10.2 BRANZ recommends

That near-horizontal surfaces such as sills be sloped at no less than 15 degrees (see Fig. 19a). If a horizontal surface is essential, for example on a parapet, it must have an impervious capping (see Fig. 19b) or be finished with ceramic tiles or similar material.

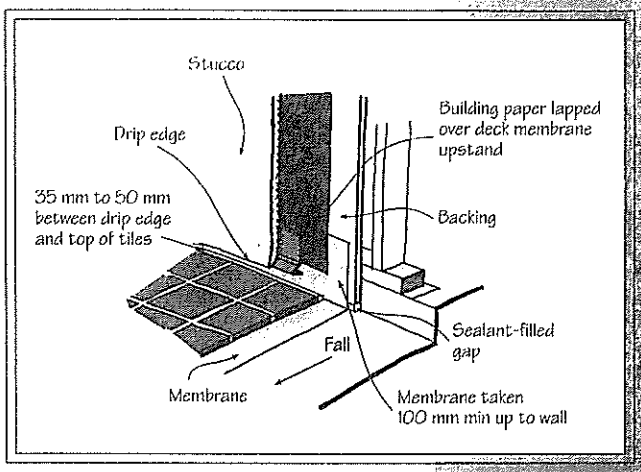


Figure 18. Wall to deck junction.

3.11. Vertical Surfaces

3.11.1 Many stucco finishes are marred by unsightly stains from misdirected water flows, particularly over smooth sponge-type finishes. Rough-finish textures break up the flow, make fine cracks less obvious and are generally more waterproof.

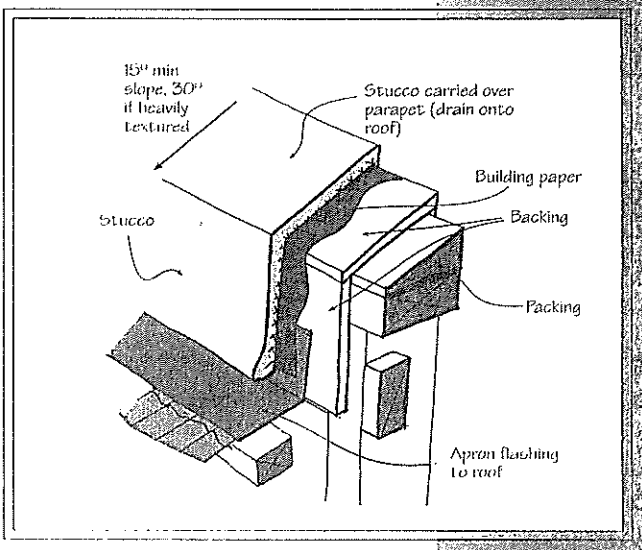


Figure 19a. Plastered parapet.

3.11.2 BRANZ recommends

Against very smooth finishes and recommends careful attention to providing drip details such as bell casts, projecting sills and drip screeds at the bottom edge of the plaster.

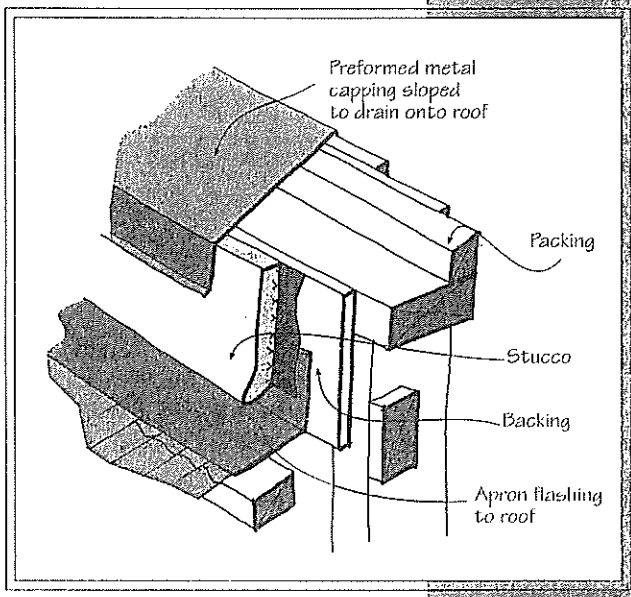


Figure 19b. Capped parapet.

3.12 Cavity Drainage and Protection

3.12.1 The cavities provided behind non-rigid backings must be designed to direct any moisture (from condensation or leaks) to the outside of the wall. The bottom of the cavity must be designed to prevent the entry of vermin (see Fig.20).

control joint can be formed through the first two coats. The final coat over the joint is only 3 mm thick and this gives a better chance for the crack to occur over the line of the control joint.

3.14.3 Another problem with 2-coat work is that the second coat with fine sand requires more water for workability. But as the plaster is being finished the surface will dry more quickly and "skin" over, and the water will drain down at the back of the second coat, causing the plaster to slump and delaminate at the lower areas of the wall. Overworking of a thick second coat to get a desired finish is also likely to cause debonding from the first layer.

3.14.4 The argument that 3-coat work takes too much time and thus increases cost is often overstated. Much of the labour is in the finishing of the surface and this is required regardless of whether it is the second or third coat. If the second coat is not the finish coat, it can be applied more quickly using a coarser sand, thus reducing shrinkage. The third coat can then be applied as a thin finish over the surface.

BRANZ recommends

3.14.5 *That all stucco claddings be constructed with three coats, and regards three coats as essential on non-rigid backings. The first two coats must have a combined thickness of at least 18 mm measured from the backing, the third coat a maximum thickness of 3 mm, and the total thickness must be no less than 21 mm.*

3.14.6 *Designers, builders and plasterers should make clients aware of the increased risk of uncontrolled cracking with 2-coat work.*

framing, fixing of linings and all other operations that cause vibrations are completed before plastering commences.

3.16.2 Linings must not be fixed until the framing has dried to the moisture content recommended by the manufacturer of the lining material. In no case should the moisture content of framing at time of lining exceed 24% as required by NZS 3602. A lower moisture content, preferably no more than 20%, will further reduce the likelihood of timber shrinkage causing cracking of the plaster. On occasions, linings have been screw-fixed after plastering has been completed. But it must be remembered that linings are a major part of wall bracing and it is desirable to have a well-braced structure before plastering begins.

3.16.3 The construction programme must make sure that all flashings are in place before reinforcing is fixed.

3.17 Trial Stucco Panels

3.17.1 The construction of a trial stucco panel, prior to commencing the main project, can be valuable insurance against expensive remedial work later. The trial allows the designer or specifier to verify that the plasterer's methods and materials are satisfactory, and serves to provide an example of the finish to be attained. If problems are encountered, timely corrective action can be taken. Trial panels are particularly important on large buildings and, where appropriate, should include examples of difficult or unusual architectural features.

3.17.2 BRANZ recommends

The specifying of trial panels for stucco contracts, particularly for large projects.

(b) Keeping a photographic job record. It is difficult to argue against good photos.

Automatic date recording on photos is an added advantage.

(c) Checking questionable design details before commencing work.

It is the designer's job to determine such factors as the materials to be used, control joint location, number of coats and finished texture. The plasterer cannot be blamed for failures resulting from design faults, particularly if he/she has brought them to the designer's notice prior to work being done.

(d) Refusing to commence plastering until the builder has completed essential work.

Wall framing should be checked for line and straightness before internal wall linings are fixed. Any straightening of studs should occur before lining, and every activity, including nailing interior lining, that causes vibration in the frame work should be completed before plastering commences. Internal linings must not be fixed until the framing moisture content is down to no more than 24%, as drying shrinkage could cause cracking of the plaster.

The plasterer should be satisfied that the wall framing is straight enough to avoid later nasty surprises which would make it difficult to get adequate plaster thickness. Plasterers should check particularly that rigid backing material has not distorted excessively. Where distortion is more than 5 mm, it is necessary to nail the sheets flat or replace them before fixing the reinforcing.

(e) Protection.
Ensuring that, before plastering commences, all adjoining building elements are protected from contact with the plaster. In particular, glass and aluminium joinery can be permanently damaged by contact with the alkali in Portland cement.

(f) Refusing to adopt bad practices to meet completion deadlines.

Failure to provide adequate curing and drying time between coats can involve much more time in remedial work.

(g) Insisting on certificates or written guarantees of material compliance.

In particular, the sand supplier should be able to guarantee that the material delivered meets the requirements of the specification.

BRANZ recommends

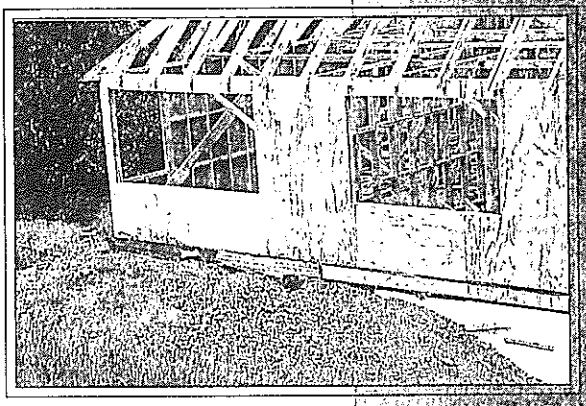
As a result of discussion with a plywood manufacturer and many plasterers, that plywood thickness be chosen according to the following table:

Plywood Sheet Thickness (mm)					
Sheets Vertical			Sheets Horizontal		
Stud Spacing (mm)			Stud Spacing (mm)		
400	480	600	400	480	600
12	12	15	7	9	12
*(9)	(12)	(12)	(7)	(7)	(9)

**Thinner sheets (shown in brackets) may be used where local materials and techniques have proven these to be satisfactory.*

Vertically fixed sheets need to be thicker because the stiffness of the sheet is lower where the face veneers are parallel to the studs.

- Joints between sheets must have 3 mm gaps.
- Sheets must be nailed at 150 mm centres around the perimeter and at 300 mm spacing in the body of the sheets.
- Nails should be hot-dipped galvanised and 2.5 mm diameter, with a length of 3 times the sheet thickness but not less than 30 mm.



Plywood is a common rigid backing for stucco.

Plywood Backing	
Advantages	Limitations
1. Efficient wall bracing. 2. Spacers can be fixed anywhere.. 3. Reinforcing can be fixed to sheets between supports. 4. Can be curved. 5. Range of sheet thicknesses to suit stud spacing. 6. 50-year durability if H3 treated.	If subject to moisture: 1. Sheets may buckle if tightly butted. 2. Sheets may distort if left exposed for more than a few weeks (especially 7 mm sheets).

(c) "**Triple S**" is a cellulose fibre insulating board, coated on one face with water- repellent black bitumen. Users must be familiar with the manufacturer's product literature.

- Sheets are available in one size only, 2700x1200 mm x 10.5 mm thick.
- Fix with 30x2.5 mm hot-dipped galvanised flat-head nails at 150 mm centres at all sheet edges and at 200 mm centres to intermediate framing, no closer than 10 mm to the edges.

"Triple S" is used in two ways:

1. as a rigid backing covered over with building paper;
2. as a replacement for building paper with the plaster being applied directly to the sheets.

When used as a substitute for building paper, it requires special attention. Seal joints between sheets with 100 mm wide strips of polythene or building paper stapled to the face of the sheets. Leave a 3 mm gap between sheets (see Fig.21). For joints at internal or external corners the polythene or building paper must extend 100 mm along each face of the corner angle.

Horizontal joints between sheets must be flashed with 100 mm wide polythene or building paper flashing strips, installed like Z-flashings.

"Triple-S" can be used on framing with studs up to 600 mm centres, but dwangs must be spaced at not more than 600 mm centres i.e. at least 3 rows of dwangs are required.

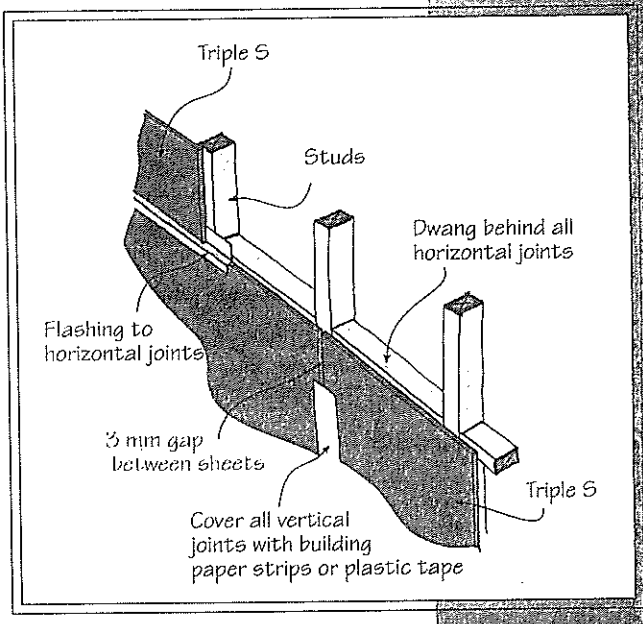


Figure 21. "Triple S" rigid backing

Fixing to wall framing is best done with 75 mm galvanised spring-head roofing nails through 40 mm diameter plastic disks and penetrating at least 35 mm into the framing timber.

With studs spaced at 400 mm centres sheets should be fixed at 250 mm centres to all studs, plates and dwangs.

Polystyrene sheets should be fixed over fire-retardant building paper.

Sheets should not be left exposed to the weather for more than 4 weeks. If left longer, wire brush the surface to remove the powdery weathered surface material, before fixing the reinforcing over spacers.

Reinforcing should be fixed at 150 mm centres to studs, plates and dwangs with fixings that penetrate at least 30 mm into the timber framing. The bottom edge of the polystyrene and plaster must be supported by a stop or bead that protrudes enough to form a guide for plaster thickness. Alternatively, the polystyrene may be supported in a rebate at the foundations or concrete floorslab (see Figs. 22 and 23).

Plaster can be applied directly to the face of extruded polystyrene (without a slip layer) because the polystyrene is a comparatively stable material which does not absorb moisture, and is weak enough to move with the plaster as it shrinks.

It is probably best suited to single storey work to overcome problems associated with shrinkage of deep floor joists. This will also limit the weight of plaster that needs to be supported by the stop or bead.

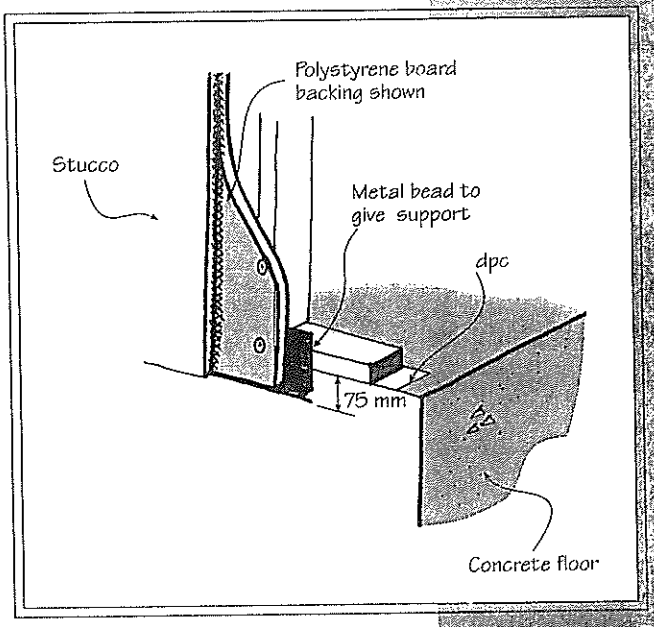


Figure 22. Metal bead support for polystyrene backing.

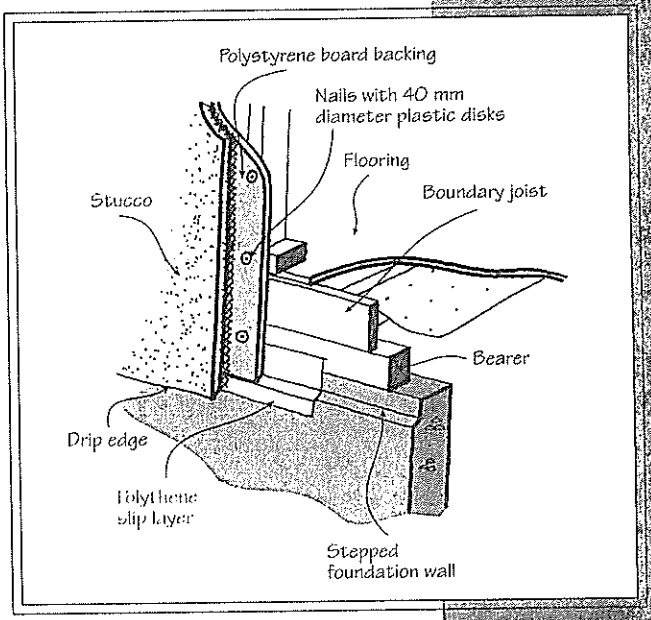


Figure 23. Polystyrene backing supported on foundation.

5.2 Non-Rigid Backings

5.2.1 In some districts, solid plaster is applied over non-rigid backing. Materials used are standard weight and heavyweight breather-type building paper, as well as self-supporting roof underlay.

5.2.2 Non-rigid backing is at times applied directly to the wall framing (without battens to space out the solid plaster). This method does not comply with the requirements of NZS 3604. BRANZ does not recommend this practice as it greatly increases the risk of water damage to the wall framing if leakage through, or condensation on, the back of the stucco occurs.

Comment :

BRANZ has no doubt that a drainage cavity behind stucco cladding is good insurance against moisture damage to framing. Conversely, it is acknowledged that apparently satisfactory results have been achieved without a cavity, but inspections of many houses more than 30 years old have disclosed extensive damage hidden behind linings.

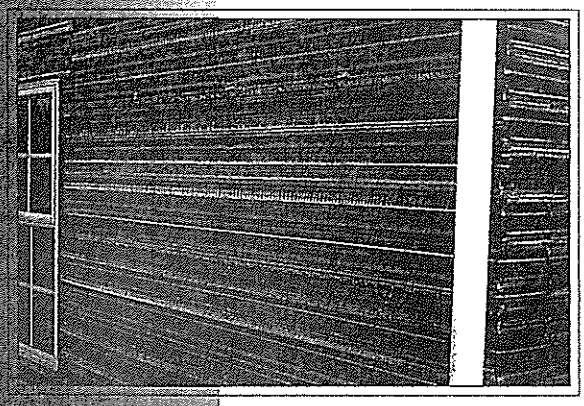
It is understood that the philosophy behind the NZ 3604 provisions is that protection of the structural frame from moisture damage is of prime importance. Should moisture for any reason penetrate the building paper adjacent to the plaster, it is necessary to have a second line of defence. This is provided by rigid backings or the cavity behind non-rigid backings. A single layer of building paper fixed to the studs provides no such protection.

BRANZ recommends

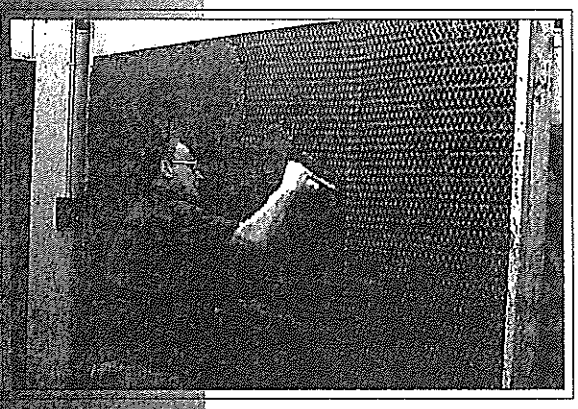
Providing support behind building paper used as a non-rigid backing. Such support should ensure that the maximum deflection of the building paper under plaster application does not exceed 5 mm..

Non-rigid Backing

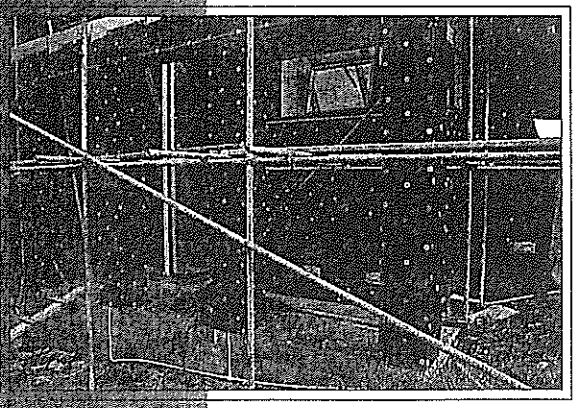
Advantages	Limitations
1. Eliminates the cost of rigid backing sheets.	1. Less robust than rigid backing. 2. Insufficient support for lighter self-furring reinforcing. 3. Does not provide wall bracing. 4. Greater risk of uneven plaster thickness (and differential shrinkage) as paper is forced back between supports during plaster application. 5. Added cost of second layer of paper and battens.



Self-furring systems can be used over non-rigid backings.



Corrugated chicken netting is suitable with rigid backing materials.



Purpose-made plastic spacers are recommended instead of the bottle tops being used here.

6.1 Self-Furring Reinforcing

6.1.1 Self-furring systems with ribs have adequate stiffness to span 600 mm from support to support and are thus suitable for use over non-rigid backings.

6.1.2 Expanded metal with corrugations is less rigid and is more suitable for 400 mm support spacing or for use over rigid backing. With larger spans over non-rigid backing the lighter materials may distort during plastering and move when the plaster is applied in the next space between studs. Rigid backing overcomes this movement.

6.1.3 Corrugated galvanised chicken netting, produced by passing chicken netting through a crimping roller, is suitable only for use over rigid backing. It cannot be pulled tight but appears to work well in practice. It has inadequate stiffness for use with non-rigid backing.

6.2 Spacers For Reinforcing Mesh

6.2.1 A wide range of materials is used. Material for spacers should be :

- compatible with wet plaster
- larger than the mesh size (practical for up to 25 mm mesh)
- easy to install
- durable
- unaffected by moisture.

6.2.2 Materials in current use are plastic tops from 2 litre milk containers, squares of fibre-cement sheet, H3-treated plywood squares, small polythene washers, purpose-made plastic spacers, strands of 4 mm diameter galvanised wire, galvanised staples, metal bottle tops, short off-cuts of H3-treated trellis timber and squares of wood fibreboard. Purpose-made plastic spacers appear to best meet all the requirements.

6.3 Galvanising of Reinforcing

6.3.1 The gauge and weight of stucco reinforcing is listed in NZS 4251. The bases for the requirements in the Standard are not clear as the amount of steel varies enormously. The following are listed in the Standard:

- galvanised metal lath, weighing at least 1.8 kg/m²
- galvanised wire netting up to nominal 50 mm mesh, with a minimum wire diameter of 1.4 mm before galvanising
- galvanised wire netting up to nominal 18 mm mesh, with a wire diameter not less than 0.9 mm before galvanising.

However, other types not shown in the Standard are also being used successfully. These include:

- square-welded galvanised wire mesh - 19 mm squares with a wire diameter of 0.9 mm, also 41 mm squares with 1.4 mm wire diameter
- expanded metal lath - corrugated self-furring lath weighing approx 0.8 kg / m², and flat sheets, weighing approx 0.65 kg / m².

6.3.2 In BRANZ opinion, the weight of the reinforcing steel has little relevance, but it is essential to have adequate galvanising.

N.B. *Zincalume-coated steel sheet must not be used for reinforcing or other components that will be in contact with Portland cement plaster.*

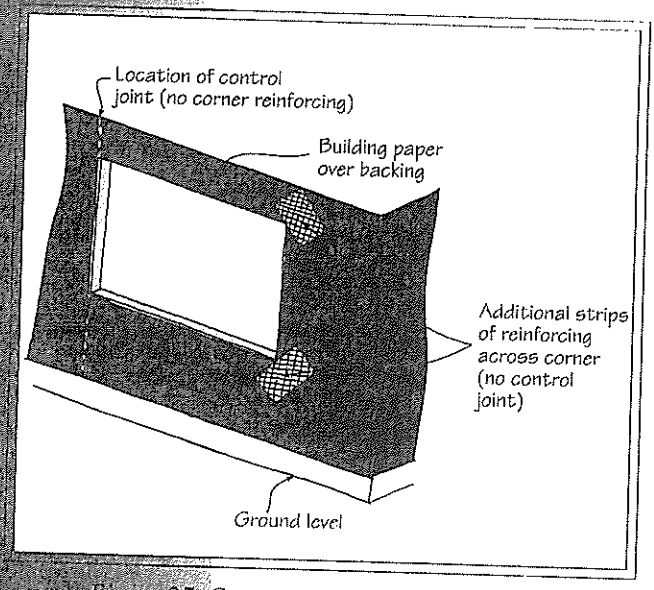


Figure 25. Corner reinforcing of opening.

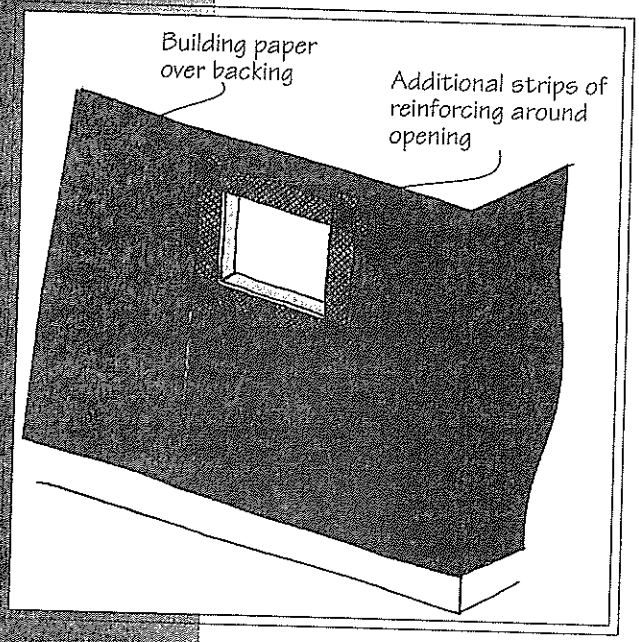


Figure 26. Reinforcing around small opening.

reinforcing all around small (less than 0.2 m^2) openings (see Figs.25 and 26).

6.4.4 Where control joints occur at the sides of an opening, diagonal reinforcing strips across the corners must be omitted to ensure that any cracking occurs at the control joints.

6.4.5 Reinforcing must be fixed at no greater than 150 mm centres, to all vertical and horizontal supports, and laps must be tied or fixed at similar spacing.

6.4.6 Site observations have shown reinforcing fixed with galvanised fencing staples; spring-head roofing nails through spacers; bent over galvanised flat-head nails and gun-driven staples. BRANZ has no evidence of unsatisfactory performance using any of these methods.

6.4.7 BRANZ recommends

For the selection and installation of stucco reinforcing, that the reinforcing:

- *be galvanised to ensure durability*
- *be furred out from the backing by between 6 and 9 mm*
- *be installed in a way which minimises deflection when the plaster is applied, by stretching it tight and/or providing sufficient support between fixings. (Proprietary systems such as "Corru-Lath", and particularly "Riblath", are more rigid than netting and reduce the likelihood of deflection)*
- *be provided with adequate laps at joints. For chicken netting, sides of rolls must be lapped by 50 mm*

6.4.10 Comment

Proprietary reinforcing

BRANZ has appraised IPSCO "Corru-Lath" and "Met-Lath", and DIMOND "Riblath". Along with all types of reinforcing, instances of stucco failure have occurred using these products. In no case investigated could evidence be found to fault the proprietary products, and site records were so poor that it was impossible to confirm that the requirements of the BRANZ Appraisal and the manufacturer's product litrerature had been followed.

"Riblath" in particular gave rise to many site comments, varying from highly enthusiastic to degrees of dissatisfaction. In BRANZ' opinion, "Riblath" has the advantage of rigidity when used over non-rigid backings and reduces the likelihood of variation in coat thickness and reinforcing location. Site evidence suggests that "Riblath" may be less tolerant of lapses in workmanship and/or material quality, particularly where plasterers use a two-coat rather than the three-coat system required. There are, however, many examples of good quality fault-free jobs using this product and there is no reason to doubt its performance when correctly used.

Proprietary products may have a higher material cost, but the ease of installation and, if self-furring, the elimination of spacers reduces the labour cost.

WELDED SQUARE WIRE MESH	
Advantages	Limitations
• low material cost • more rigid than chicken mesh • hot-dipped galvanised after manufacture • comes in rolls permitting long runs without end joints • can be lapped in any direction.	• high labour content • extra cost of furring spacers • labour cost of fixing spacers.

CRIMPED CHICKEN MESH	
Advantages	Limitations
• self furring • low material cost • hot-dipped galvanised after manufacture • comes in rolls permitting long runs without end joints.	• requires rigid backing • cannot be stretched tight.

7.2.3 BRANZ recommends

That plastering sands comply with the following:

(a) the grading of base coat and flanking coat sands shall be in accordance with the ASTM C897 grading envelope as given in Figure 27 (a maximum tolerance of 5% outside the envelope on one sieve size only is acceptable);

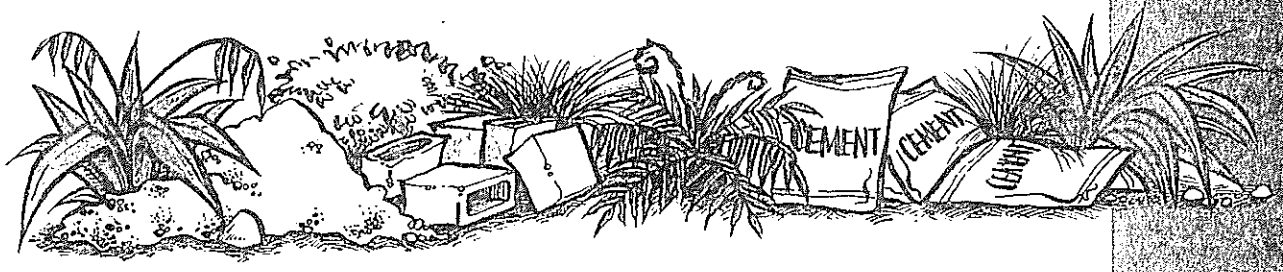
(b) finishing sands shall pass through a 2.36 mm sieve with no more than 3% passing the 75μm sieve;

(c) as a control on consistent sand supply the fineness modulus from any plant shall not vary by more than 0.4 (no limits are required for maximum or minimum fineness modulus);

(d) the sand equivalent shall be 60 minimum (this is a measure of cleanliness - see Appendix B for a simple field test for cleanliness);

(e) the voids content for base coat and flanking coat sands shall be 45% maximum, and no more than 50% shall be retained between any two consecutive sieves (and still stay within the grading envelope).

For finishing sands the voids content is not relevant provided the finishing coat thickness does not exceed 3 mm.



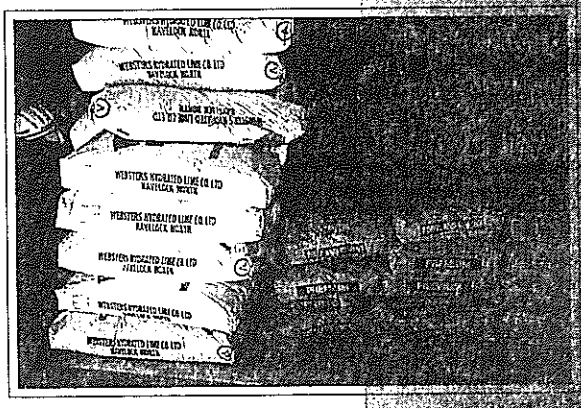
7.3.2 The advantages of lime are:

- it provides good workability to the mix
- it is especially useful to improve mixes with poorly-graded or poorly-shaped (manufactured) sand
- it replaces some of the more expensive cement
- it gains strength and hardness slowly, reducing the incidence of shrinkage cracking
- it has good water retention properties, so that the cement is not starved of water by high suction in the backing or previous coat. This also reduces the likelihood of shrinkage cracking.

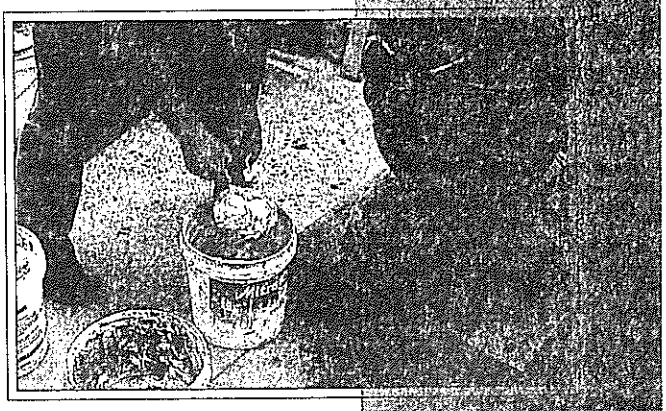
Bags of lime should be stored in a dry place. Any lumps in the lime must be sieved out.

7.3.3 The alleged harsh effects of lime on the hands can be reduced or eliminated by the use of barrier cream or wearing rubber gloves. In reality cement is potentially more harmful to the skin than lime, and protection should be a normal practice.

7.3.4 BRANZ strongly recommends the use of lime in the plaster, preferably in the form of lime putty.



Bags of lime should be stored in a dry place.



Adding lime to plaster mixes has a number of advantages.

7.4 Admixtures

7.4.1 Proprietary liquid admixtures are often used in plaster, added in small quantities during mixing. The most common are plasticisers that improve the workability of the mix. Other products are waterproofing agents and plaster

bond, tensile strength or water-proofing properties of the plaster. Increasing the amount of polymer reduces water requirements for workability and thus reduces subsequent shrinkage cracking. Polymer-modified plaster application requires special skill and knowledge, and the product must not be retempered. Examples of plaster modifiers are:

- PVA (polyvinyl acetate)- based materials used to improve bond. They should not be used in stucco exposed to the weather as water can break down the PVA;

- SBR (styrene butadiene rubber) - based materials, used to improve bond, waterproofing and tensile properties. They can be used in damp situations;

- Acrylic modifiers, which can improve bond, water-proofing and tensile properties. They can be used in damp situations.

N.B. *Both SBR and acrylic modifiers must incorporate a defoaming agent when manufactured. Site dosing with a defoaming agent is not satisfactory as accurate dosage is critical. Excessive mixing (in excess of 2 minutes) can cause excessive air entrainment and destroy waterproofing properties.*

7.4.3 Plaster modifiers reduce the amount of moist curing required for the plaster. Some manufacturers state that provided the plaster is protected from sun and wind to avoid rapid drying and subsequent shrinkage cracking, moist curing is unnecessary. BRANZ believes it is wise to use some moist curing for any Portland cement product. **See recommendation under Section 8.0.**

used only in the final coat. Pigments must be colour-fast and unaffected by the alkali in the plaster.

7.6.2 Obtaining a consistent colour requires very accurate measuring of ingredients, consistent curing and ambient conditions, and meticulous attention to mix consistency. Colour variations may also occur where parts of the building are sheltered from the weather while other parts are fully exposed. In the USA, pre-bagged coloured plaster mixes are available from suppliers, thus greatly increasing the chance of a successful end result.

7.6.3 If site mixing is contemplated it is recommended that sufficient quantities of cement and pigment are dry mixed to complete the whole job. Adding quantities of pigment to each batch of plaster as it is mixed will invariably give disappointing results, with noticeable colour variations between batches.

7.6.4 Another drawback of using coloured plaster is that the stucco is left unpainted. This increases the risk of water penetration and of corroding the reinforcing and decay of framing timbers. Hairline cracks become very visible as moisture leaches out and causes efflorescence. Pigmented plaster which is dark in colour will have higher surface temperatures, which may produce cracking due to thermal stresses. Some plasterers prefer to use coloured sand and white cement to produce coloured work, but the colour range is limited. Most plasterers would like to avoid the use of pigments. (See paragraph 3.15.2 for comments on water repellent treatments.)

7.6.5 BRANZ does not recommend the use of pigmented plaster for exterior locations exposed to weather but, if specified, it should be restricted to light colours only with pre-batched and pre-bagged materials, and be used only in the final coat.

8.2.3 Stronger cement-rich mixtures tend to have greater drying shrinkage, especially if used with fine sands. This increases the risk of large cracks.

8.2.4 A given amount of sand has least volume when saturated or totally dry. When damp the volume increases, described as **sand bulking**. Allowance for this should be made when using damp sand by increasing the amount of sand by approximately 12.5%.

e.g. a 1:1:6 nominal mix should use 1 bucket of cement, 1 bucket of lime and 6.75 buckets of sand.

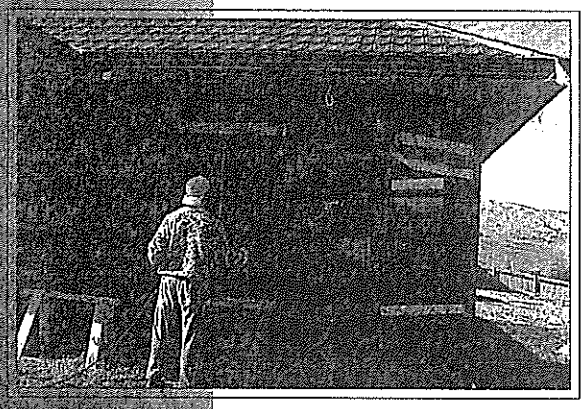
Cement and sand quantities should be measured accurately using a suitable container.

8.2.5 BRANZ recommends

- *the use of lime, preferably as lime putty, in the plaster mix with a binder to sand ratio of no greater than 1 : 3. Lime is likely to be beneficial by improving workability without excess water if using poorly-graded and poorly-shaped (manufactured) sands;*
- *that if lime is not used, a cement to sand ratio no stronger than 1 : 4 may be used with well-graded clean sand and good curing;*
- *that cement and sand be measured accurately by volume using a suitable container (not a shovel);*
- *that mixing times be controlled, especially when using an admixture. A trial mix should be used to establish correct mixing time as not all mixers and sands give the same result. Once the time is established use a simple time switch on the mixer.*

summer temperatures occur, curing may be assisted by hanging scrim or shade cloth over the plaster to give shade, reduce the effect of drying winds and to retain moisture.

8.7.3 What is enough curing? "If the plaster is changing colour and it has gone white, it has been left dry for too long", stated one plasterer. Certainly, hosing the plaster first thing in the morning and when going home at night is not adequate in summer. Proprietary sprinkler systems with programmed timers are very useful, especially over weekends when sites may not be attended.

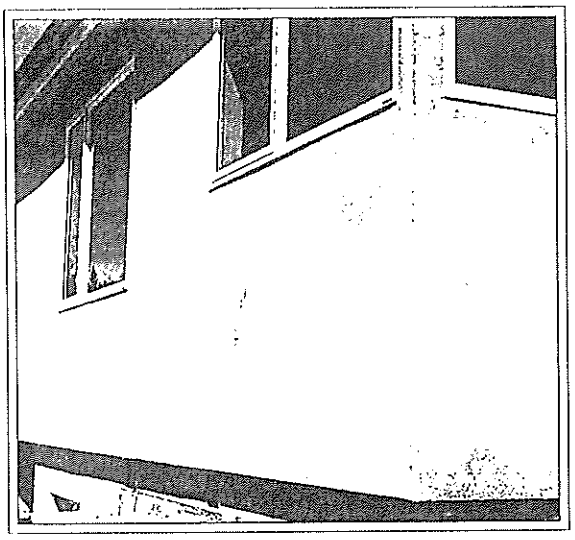


Hosing night and morning is not enough for plaster to cure properly in summer.

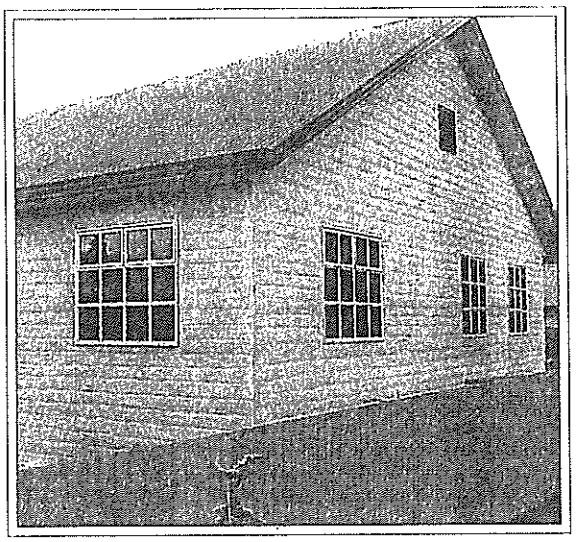
8.7.4 Early painting of plaster work is favoured by some as a means of retaining some of the mixing water for curing and, as the paint is usually light in colour, it helps to keep surface temperatures lower. This approach appears to work where an acrylic primer coat is used as this allows some water vapour to diffuse slowly through it. It is not suitable for high-build coatings, as these are far less permeable and early application is likely to result in blistering if moisture is trapped in the plaster.

8.7.5 BRANZ recommends

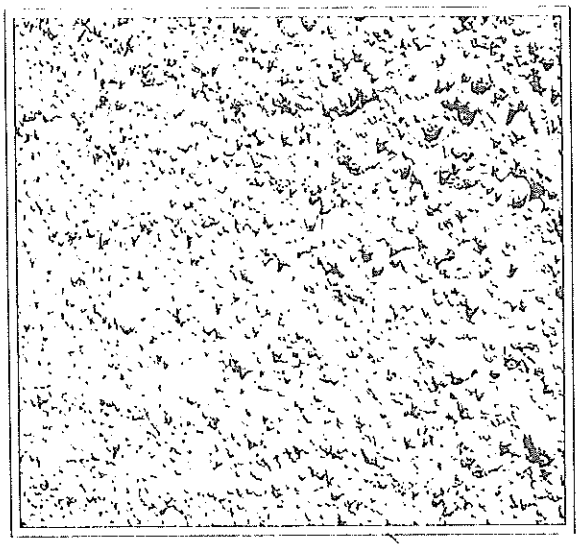
That unmodified plaster be wet cured by continuous mist spray or protection with wet hessian or shade cloth, for not less than 4 days followed by 2 to 3 days drying, and that modified plaster (see Section 7.4) be wet cured for one day and shaded for a further 3 to 4 days.



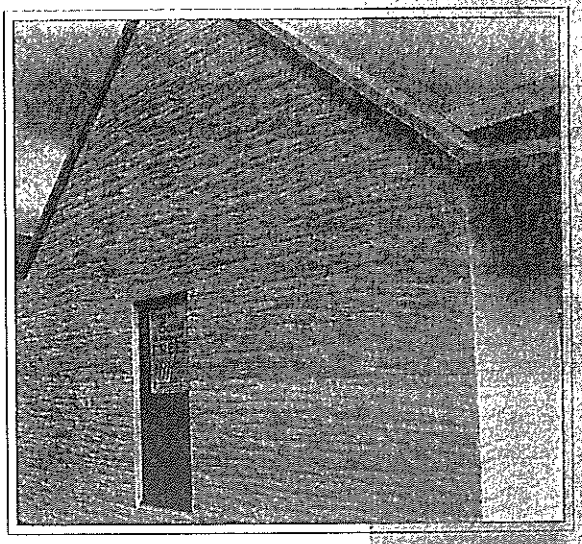
Sponge finish.



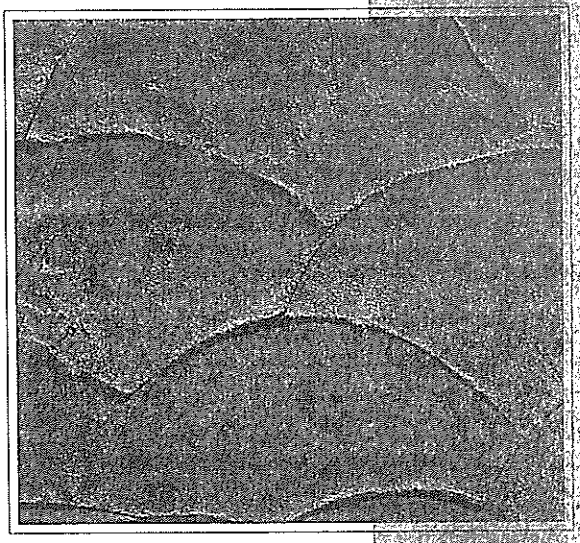
Arrowtown.



Spatter dash (coarse).



Stone finish.



Swirl.

Another attractive finish.

10. Appendix C: e-Matrix