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An Outline of DAMP - a KBS Diagnostic System

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ABSTRACT

DAMP is an 'Expert System' or 'Knowledge Based System' (KBS) to aid diagnosis of causes of moisture damage found in buildings in New Zealand. This paper gives an outline of the current version of DAMP, which is still under development at the Building Research Association of New Zealand, operating in the CLASS language developed at University of Auckland with BRANZ support.

AN OUTLINE OF DAMP - A KBS DIAGNOSTIC SYSTEM

1. INTRODUCTION

DAMP is a rule-based computer system for diagnosing moisture problems in buildings. The term DAMP strictly refers to a formal knowledge base, which, in this case, is accessed via the CLASS language on a host computer (VAX 750). In practice, the term is also used more loosely to include the associated technical knowledge and experience concerning moisture behaviour.

The reasons for interest in "expert systems" is that they may be able to make experience available to the inexperienced, and that they will perform consistently without overlooking facts or interpreting them differently from one time to another. In the case of diagnostic systems, these advantages come at a cost to generality and reliability, because the knowledge is imperfectly developed.

DAMP considers three types of moisture problem:

- (a) Mildew growth for condensation
- (b) Stains
- (c) Rot

It operates interactively, asking questions until there are grounds for a diagnosis, or all feasible lines of enquiry are exhausted. There are several forms of on-line help. The system can cope with some uncertainty of answers, and will consider more than one feasible cause. Each interview can be recorded to a file, in full and/or in summary, and comments can also be included in the file.

DAMP is not at this stage released for use except within the Building Research Association of New Zealand.

2. The DAMP Knowledge Base

- : "Water is neither created nor destroyed (- building moisture always comes from somewhere)"
- : "Moisture is the necessary and sufficient condition for decay, corrosion" Anon.

The appearance of moisture in a building is the result of largely deterministic and well established physical process. In principle, programs to fully analyse the moisture state of a building are possible. For design purposes this may be a feasible option, although even in this case a full individual analysis might be unrealistic. As a diagnostic aid such an analysis cannot be applied, because the initial and boundary conditions for the problem are not known, and the actual building details are not fully known either. For reasons like these, DAMP is based largely on observed associations and qualitative data applicable in the New Zealand setting.

BRANZ 20y+ experience began with published literature, much of which is sound but some quite defective. A long-standing advisory service using human "experts" handle over 500-1000 NZ enquiries annually on moisture problems. At this level of enquiry it becomes possible and necessary to

look for common factors, and to exploit them if present. It has been noted that, in at least some cases, these experts could produce apparently correct diagnosis from brief descriptions. However, it is also noted that such cases often invoked some call on an extensive knowledge of building practice and occupant habits, sometimes triggered by minor cues in the description. These associations normally occur at subconscious level, and are rarely noticed unless very deliberately sought for..

"DAMP" has already evolved through several stages. In one form it was a student project on Expert Systems (Sachdeva 1985). At present a more comprehensive version is under development at BRANZ, using the CLASS language (Dechapunya, 1986, M. Buis et al 1986).

Conversion of this associative knowledge base into rules, began with a separation into 11 building types, 8 symptom types, 6 sources of water, and 6 moisture transfer mechanisms. A schedule of these groups is given in Table 2, and a diagnostic tree illustrating the general scheme is given in Figure 1 .

Rules have been established to date for only one building type - domestic. Simple combinatorial expansion, using Table 2, shows that these different building symptom types, sources and mechanisms can occur in about 300 possible combinations. However, potential users are not expected to know much about moisture sources or transfer mechanisms, but they can be reasonably asked about the patterns applying to their symptoms (eg, where the symptoms are seen; if, how, and when they vary) and some information about the building itself, and about the way it is used. The number of possible combinations using this data promptly runs into thousands.

DAMP is fortuitously saved from being overwhelmed by the fact that the matrix of combinations is only sparsely filled. Only some 10% - 25% of the possible combinations are considered to exist and to add usefully to diagnosis.

The DAMP Knowledge Base System firstly divides the moisture problems into three groups:

- (a) mildew &/or surface condensation
- (b) stains
- (c) rot

Guidance is also available to help a user decide which if any of these conditions they may have. (This illustrates the beginning of the uncertainty - if someone is not clear what the problem is, the chances of getting accurate symptom descriptions must be suspect also).

In the case of mildew/condensation, the age of the building is established, and then the location within the building. Age is important only to establish whether or not the building is "new". If so, the chances are that the problems arise from construction moisture, ie, the use of timber or concrete which was installed wet or has become wet from rain, dew, or spillages during construction. These reservoirs of moisture in most cases dry off in the first few months of use. Furthermore, it is not usual for other, occupant-generated, sources of moisture to have accumulated sufficiently to be troublesome at that stage. Division into various locations in the building follows. As one might expect, problems in one room will not usually have their origin in another, although it is possible for more than one room to be affected by some common factor,

notably the degree of heating and ventilating. These two items are key factors, and are the hardest to establish adequately. Occupants will clearly have no knowledge or interest in the real causes of mildew/condensation, which relate to local moisture and temperature conditions. These, in turn, depend on the temperature differences between indoors and outdoors, the amount of indoor moisture released, the amount of ventilation and the insulation level. Consequently, one must ask indirect questions concerning heating and ventilation practices, and make assumptions about how equipment is probably being used. DAMP has been designed to default to an assumption that heating and ventilation are not sufficient if there are not adequate alternate indicators.

Although it is usual for problems in one location not to have their origins far away, there are some notable exceptions. Leaks have always been notorious for appearing far from their origin, but at least they are at a lower height than the origin. But there is a class of problems leading to stains, mildew, or dripping on ceilings, where roof moisture comes from subfloor ground. This can occur in buildings with masonry veneer or stucco walls, or with through-vented linen cupboards, that allow subfloor air to pass to the roof space. In cold clear weather, this process carries huge quantities of water into the roof. DAMP is set up to detect these cases, giving appropriate repair advice.

The "stains" and "rot" options do not bother about building age and go straight to identifying the location of the problems. These options are not yet as fully developed as the "mildew" option. The "rot" option is particularly difficult, because rot seems to be a somewhat individualistic phenomenon, often arising from specific local details, or from gross inattention. There are however a number of strong clues in the location and especially the patterns of stains and rot, which help point to probable causes. Whilst any well-defined pattern is likely to be a pointer to a particular cause, the patterns DAMP looks for are geometric patterns (particularly those corresponding to the construction elements of the building, such as the location of studs), and whether the stains change with cold, with wet, or with time.

In Figure 2 is a representation of the decision tree used in preparing the "rot" option of DAMP. This option is illustrated as it is the simplest of the three options. Although very cryptic, Figure 2 should give some idea of how the process functions, with single, multiple, or zero conclusions being offered in various circumstances. Notice that even where a firm conclusion is indicated, there is still no detail on exactly where or how the moisture has entered. That information, plus confirmation of the diagnosis, must be supplied by direct inspection of the particular site.

There is a major difficulty in defining what a given Knowledge Base consists of. Figure 2 may be taken as a definition, at one level, of a section of the DAMP Knowledge Base. But this definition only specifies the names of the items and their interconnection, it does not detail the items in full. A complete definition of the Knowledge Base could be taken to be the full listing of knowledge data used by the computer system. But, in many cases, this knowledge is inseparable from the program which interprets it, and would then be a grossly inadequate definition. CLASS provides that the DAMP Knowledge Base (or any other knowledge base it may be working with) is quite separate from the program, and can be separately listed. But the meaning of the Knowledge Base even then is affected by how CLASS uses it, and, with the sheer bulk of the listing, this is still not satisfactory as a definition. This difficulty will become greater if these systems become capable of creating new solutions, rather than being largely decision trees as at present.

Sample Run

In an Appendix, is a sample run using DAMP. The example given is based on a real case, but is conducted to illustrate some of the support features of DAMP. (This example does not necessarily use the most recent version of the Knowledge Base.)

This example shows that it is possible to pick up from a previous interview, and alternatively asks whether the user wants some basic guidance. The 'yes' choices made here shows what sort of help is available. These are indicated in steps 1-6.

At step 7 it has been ascertained that the problem is mildew (or surface condensation, which is equated to mildew), and the age of building is sought to determine if construction moisture is likely to have contributed. In this example, construction moisture is not to blame.

Then the location of mildew is established (step 9). Had this been on interior surfaces, there would have been supplementary questions about the heating and ventilation of the house. But, since the problem was in a wardrobe, and in addition the room was not normally used, then the heating and ventilation are unlikely to be of influence.

At this stage DAMP concluded that it had enough evidence to form a diagnosis, and two possible conclusions are offered. In the real case, it was found that the cause was a roof leak, evidenced by water stains on the underside of roof tiles above the wardrobe.

An extension to the 'interview' is then illustrated in steps 13-15. At the end of step 13 we change the 'observed location of mildew' from 'wardrobe' to 'on external walls'. Note that DAMP then seeks some information on the heating and ventilation, concluding that these are adequate in this case, and the occupants should curb their moisture emission. Note particularly that the heating and ventilation questions are indirect. The truly relevant question is not asked as it is believed the interviewee is unlikely to know.

3. CONCLUSIONS

Some features of moisture-problem diagnosis in buildings can be achieved with reasonable reliability by rule-based systems, and one such system - DAMP - has been briefly outlined.

Whilst systems such as DAMP can be a useful aid, there are also a number of difficulties which are hampering their advance. These must be solved before the full potential of these systems can be realised.

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Factor	"Intuitive-Based" System (Human)	"Rule-Based" System (Computer)
Availability to date	available, (but few good experts)	not available
Reliability of diagnosis	high	variable
Limits (to extent of accessible knowledge)	unlimited	rigid limit
Flexibility (to cope with unexpected variations)	high	zero
Consistency of diagnosis	usually consistent	totally consistent
Recordability of case details	records often imperfect	records can be exact
User training needs	very lengthy	minor
Form of knowledge	associative	heirarchal

TABLE 1. COMPARISON OF TWO FORMS OF THE "DAMP" KNOWLEDGE BASE

<p><u>Building Types:-</u></p> <ol style="list-style-type: none"> 1. Houses 2. Multi-apartment 3. Office 4. School 5. Dry Process Manufacture 6. Wet Process Manufacture 7. Warehouse 8. Cold Stores 9. Swimming Pool Hall 10. Sports Hall 11. Laundry 	<p><u>Symptom Types:-</u></p> <ol style="list-style-type: none"> 1. Mould 2. Visible water 3. Water stains 4. Other stains - Tar Stains - Pattern Stains 5. Paint Blistering 6. Rot 7. Corrosion
<p><u>Schedule of Available causes:-</u></p> <p><u>Moisture Sources</u></p> <p>Construction moisture</p> <p>Ground water</p> <p>Rain leaks</p> <p>People (breathing washing cooking)</p> <p>Process moisture</p> <p>Pipe leaks</p>	<p><u>Transfer Mechanisms</u></p> <p>Air movement</p> <p>Seepage/capillary</p> <p>Sunshine/temperature changes</p> <p>Condensation</p> <p>Vapour diffusion</p> <p>Storage</p>

TABLE 2. SOURCES AND SYMPTOMS OF BUILDING MOISTURE

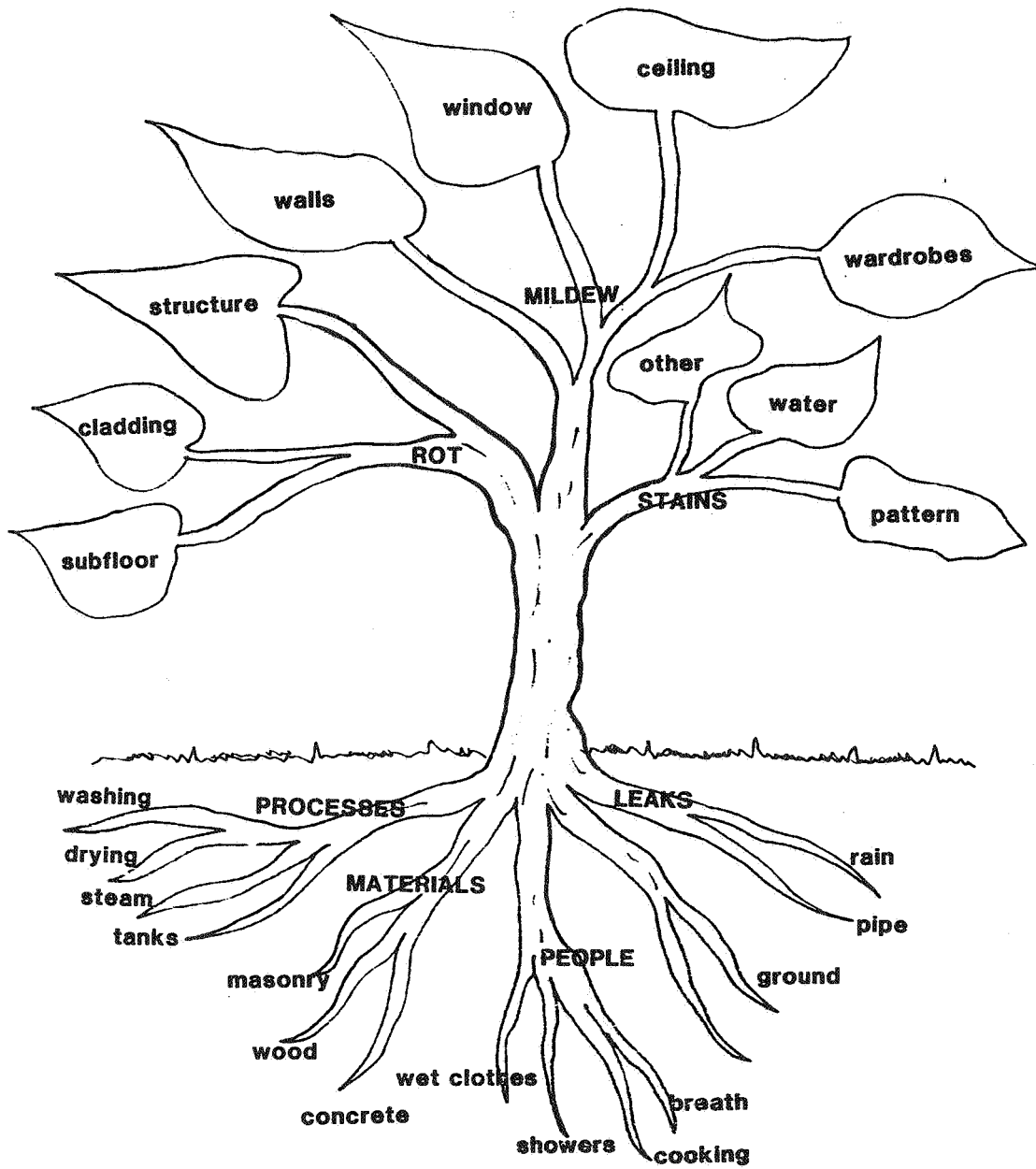


FIGURE 1 The Diagnostic Tree

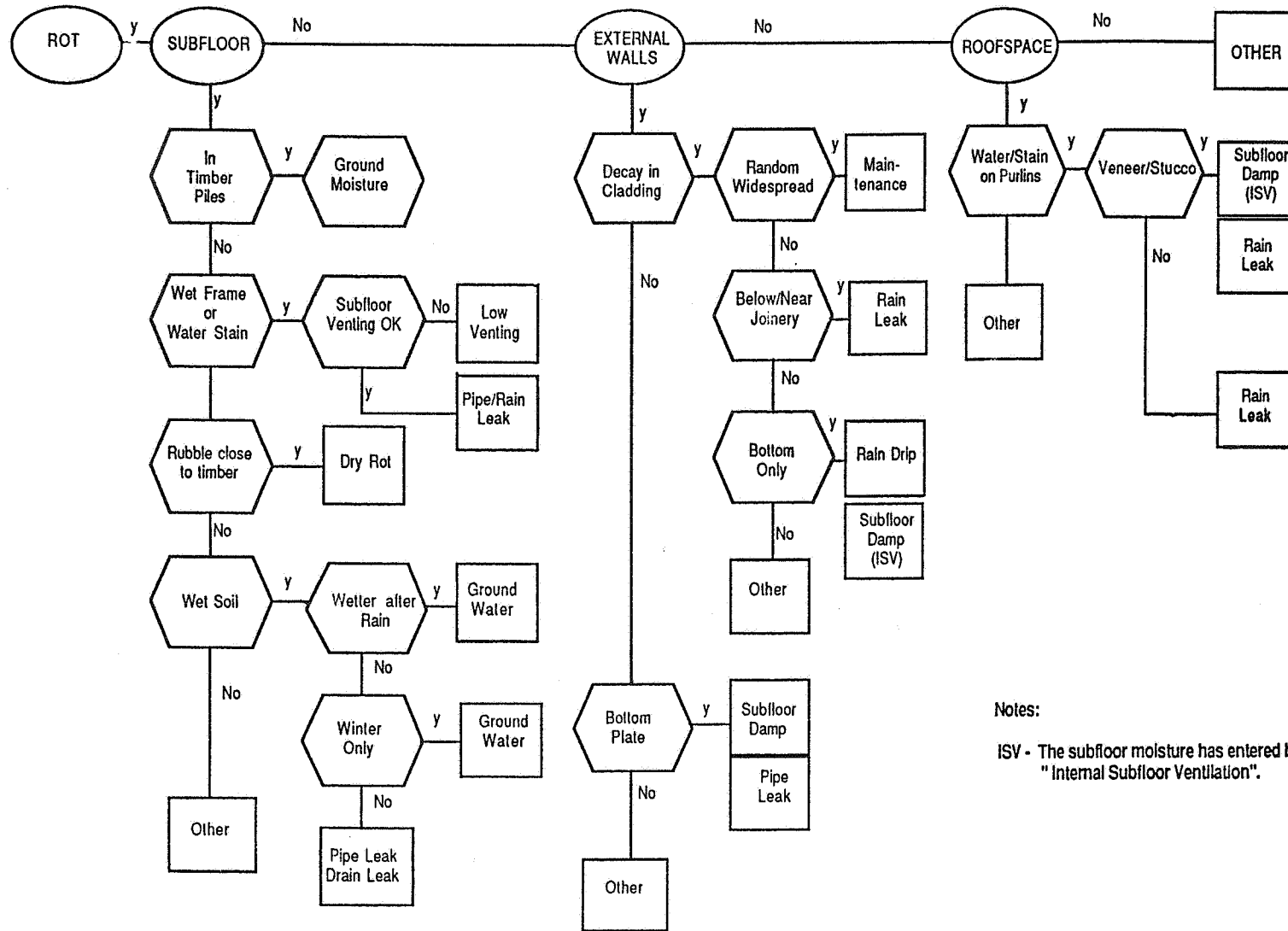


FIGURE 2 Summary of present form of "Rot" option of "Damp" diagnostic rules

a sample case

DAMP KNOWLEDGE BASED SYSTEM

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At present BRANZ accepts no liability for the information contained in this knowledge base or any advice given during this consultation.

Do you wish to continue from a previous session [N] ? n

The DAMP system is intended to be used as a diagnostic aid to moisture problems frequently encountered in New Zealand houses.

The system will attempt to learn more about your problem by asking you questions about the problem. Once the system has enough information to determine the likely cause of your problem, it will display it, along with a discussion of the problem and a number of actions you can take.

--0--

Do you want further information about the DAMP system ? yes

How To Use The DAMP System

The DAMP System will try to learn about your moisture problem by asking you questions about your situation. It is important that you try to answer these questions as accurately as possible. If you do not know the answer to any question, you may type "UNKNOWN". The system will continue using other information.

DAMP will sometimes ask you to choose from a list of alternatives, such as the following:

- Do you want to choose:
- 1 - The first alternative.
 - 2 - The second alternative.

Please type the number of the appropriate choice >

You can type "1", "2" or "UNKNOWN" in response to this question.

DAMP will also ask you questions such as this:

Do you want further information about the DAMP System ?

You can type "YES", "NO", "Y", "N" or "UNKNOWN" to this question.
(All communication with DAMP can be either upper or lower case.)

Before you use the DAMP system, it will be useful to know some basic information about the house, such as its age, the type of wall material used, whether it is insulated. This will speed up the consultation process. If you do not know any of this information, just type "UNKNOWN" when you are asked a question about it.

Once the system has collected enough information to be able to make a judgement about the likely cause of your problem, it will display its conclusions to you. Each conclusion will identify the most likely cause, give some background information, and outline a number

of possible actions you can take. If you want further information about the findings you may ask for this also.

--1--

Do you want information about how explanation works ? n

--2--

Do you want information about how to change your answers ? n

--3--

Type the address of the building for reference (in one line).
> 123 noname road

Consultation Starts.

--4--

DAMP uses the symptoms you can see, and tries to match these with the causes which might apply, and where possible suggests the action that should be taken to remedy the problem.

DAMP recognises three main groups of symptoms:

- 1 - Mildew.
- 2 - Stains.
- 3 - Rot in Timber.
- 4 - Not sure.

Please type the number of the appropriate description > 4

--5--

The following symptoms are indicative of moisture problems:

Mildew is usually indicated by any of the following:

- The stain has fuzzy edges and is mainly one colour (usually black).
- The stain smudges when touched and there may be a musty smell in the area.
- The stain has fibrous growths on the surface (like microscopic plants or vines) when inspected closely.
- On glossy surfaces, mildew can be wiped or washed off, on matt surfaces it can sometimes be vacuumed off, but will regrow.

Stains caused by moisture may be indicated by:

- The stains do not look like fibrous growths and do not come off easily or spread when touched.
- The stains have sharp edges, and may have more than one colour

Rot in timber is usually indicated by any of the following:

- Wood is soft when pressed by a thumbnail or spongy when pressed by a finger.
- Patches of wood which have shrunk inwards.
- Any soft white fibrous growth over the wood.

Does your problem have any of the above symptoms ? y

--6--

Which of the problem types does the symptom suggest:

- 1 - Mildew.
- 2 - Stains.

- 3 - Rot.
- 4 - Not sure.

Please type the number of the problem that seems likely > 1

--7--

What is the age of the building:

- 1 - The building is less than 6 months old.
- 2 - The building is 6 - 12 months old.
- 3 - The building is 1 - 20 years old.
- 4 - The building is over 20 years old.

Please type the number of the appropriate age > 4

--8--

From the following description of floor:

- 1 - Slab-on-ground floor less than 12 months old.
- 2 - Slab-on-ground floor more than 12 months old.
- 3 - Suspended floor.

Please select description of floor >3

--9--

What is the location of the mildew:

- 1 - On the ceiling.
- 2 - On external walls.
- 3 - On internal walls.
- 4 - On the floor.
- 5 - In wardrobes or cupboards.
- 6 - On drapes.
- 7 - Other.

Please type the number of the mildew location > 5

--10--

Are damp items often stored in the wardrobe or cupboard ? n

--11--

Is the room / wardrobe in normal use ? n

Reference : 123 noname road

Determining the likely cause of the problem:

WALLS ARE INTERNALLY VENTED FROM SUBFLOOR SPACE.

Normally internal walls are not cold enough to allow mildew growth. But if they are vented internally from the subfloor - no longer a recommended practice - this not only brings moist subfloor air into the wall, but also cools the wall so that it collects mildew.

Action: Stop up internal wall vent openings.

Improvement should occur almost immediately.

Another possible cause is:

PIPE OR RAIN LEAKS.

Mildew requires moisture for survival, and usually this moisture is generated by occupants. If the space is not occupied then it is not likely that moisture will come from people, and rain or pipe leaks become the most likely source of water.

Action: Find the leak and fix.

Improvement should normally be seen within days or weeks.

--12--

Would you like to see some more technical information about heating, insulation and humidity ? n

--13--

Would you like to see a list of related publications ? n

Would you like this session to be saved as a case study for BRANZ [Y]? y

[change] Change an answer to a question
[knowns] Show the answers given to questions
[comment] Write a comment to BRANZ
[run] Start another session
[help] Provide more detailed information about options
[?] Display this menu

[exit/quit] Exit the system

Command > knowns

The following data has been input:

=====

--0-- wantInstructions = true
--1-- wantExplanationHelp = false
--2-- wantChangeHelp = false
--3-- reference = 123 noname road
--4-- usersProblemType = notSure
--5-- hasSymptom = true
--6-- theSymptom = mildew
--7-- age = over 20 years
--8-- usersAgeOfConcreteFloor = none
--9-- location = wardrobe
--10-- wetItemsStored = false
--11-- roomInUse = false
--12-- wantTechnicalInformation = false
--13-- wantBibliography = false

Command > change

Enter the answer number(s) [type "?" for list of numbers] > 9

--9--

What is the location of the mildew:

- 1 - On the ceiling.
- 2 - On external walls.
- 3 - On internal walls.
- 4 - On the floor.
- 5 - In wardrobes or cupboards.
- 6 - On drapes.
- 7 - Other.

Please type the number of the mildew location > 2

--14--

Can you indicate some of the features affecting the average ventilation of the space:

- 1 - The building is locked during the working day.
- 2 - The house is aired daily for more than 5 hours / day.
- 3 - The building is well ventilated in some other way.
- 4 - Not sure.

Please type the number of the appropriate ventilation > 1

--15--

We now need some information about the degree of space heating used. Since the information ultimately needed is not likely to be available, the following are indirect indicators:

- 1 - The building is centrally heated.
- 2 - Two or more nightstores are used.
- 3 - Heating is typically on for at least 4 hours per day (in winter) in the affected space.
- 4 - Temperature in the affected space is nearly always 6-7 degree C warmer than outside.
- 5 - Temperature in the affected area is often less than 6-7 degree C warmer than outside.
- 6 - Only limited heating is used.
- 7 - Unsure about the heating used.

Please type the number of the appropriate indicator > 2

Reference : 123 noname road

Determining the likely cause of the problem:

TOO MUCH MOISTURE.

It is unusual to get mildew when the heating and ventilation are both sufficient. I have inferred that they are in this case. If so it is likely that the cause of mildew is that too much moisture is being released, from things such as:

- flueless gas, kerosine, or LPG heaters
- showers
- people
- indoor clothes drying

Or perhaps the insulation is not adequate where mildew has formed.

If you wish to look for further possibilities, then use CHANGE command to alter your replies to heating and

ventilation questions.

Would you like this session to be saved as a case study for BRANZ [Y]? y

[change] Change an answer to a question
[knowns] Show the answers given to questions
[comment] Write a comment to BRANZ
[run] Start another session
[help] Provide more detailed information about options
[?] Display this menu

[exit/quit] Exit the system

Command > exit