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MOISTURE DAMAGE TO HOMES IN CHAMPAIGN CO., IL

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ABSTRACT

Information about moisture damage to homes is often anecdotal. While case studies are helpful in illuminating construction problems, they provide no basis for gauging the seriousness of issues raised. The purpose of this study is to determine how widespread and severe moisture damage is within Champaign Co., IL.

Home inspections were conducted on 670 single-family residences in Champaign Co., IL (5600 degree-days). All visible surfaces, including foundation, floor framing, interior surfaces, exterior finishes, attic sheathing and attic framing, were inspected. Wall framing and sheathing were not exposed during the inspections. The inspection reports were compiled into a database. Data fields were chosen to exhibit damage conditions and explanation conditions. The damage conditions due to water (liquid and vapor) were highlighted. Explanatory conditions were primarily mechanical (e.g., backdrafting combustion appliances), evaporative (e.g., exposed soil in a crawl space) or liquid (e.g., roof leak) sources of water.

The results show that 5.4% of the homes suffer major moisture damage--that is, damage which necessitates the repair or replacement of structural members (usually floor framing or attic sheathing). Another 35% suffer some sort of moisture damage to the visible surfaces, although this damage is often quite minor (for example, water spotting on ceilings or signs of condensation on windows).

The study demonstrates a clear correlation between the presence of evaporative sources of moisture and damage to the structure. The evaporative sources noted are concerns of construction practice, not of "lifestyle".

INTRODUCTION

The purpose of this study is to identify the scope and severity of moisture induced problems in single-family dwellings in the Champaign/Urbana, Illinois area. In particular, it seeks to find an association between moisture damage and sources of moisture. Information about moisture damage to homes is often anecdotal. In the effort to establish an accurate basis for future research, the Small Homes Council/Building Research Council (SHC/BRC) undertook the analysis of available data regarding moisture damage in the geographic area in which the Council is located. The results of that analysis are the subject of this report.

Research in construction technology must address existing problems. The research agenda proposed by the Building Thermal Envelope Coordinating Committee, BTECC, (under the auspices of the National Institute of Building Sciences, NIBS) includes as a priority objective the establishment of a data base on moisture problems. [Moisture Control in Buildings, Erv Bales, Heinz Trechsel, eds., BTECC, Moisture Control in Buildings RCC, Workshop Proceedings, Sept. 24-25, 1984]. There have been few studies to date which have studied moisture damage in existing homes. One such study is "Moisture Induced Problems in NHA Housing. Analysis of field survey results and projections of future problems" by Marshal Macklin Monaghan Limited for the Canadian Mortgage and Housing Corporation. In this report the authors intended to correlate the reported incidence and geographic distribution of moisture induced problems in NHA housing. Their database consisted of 201 dwelling units each of which had reported a problem. Studies by George Tsongas in Portland, OR and Spokane, WA (100 units in each city) focused on the the risk of moisture damage only to wall cavities from the addition of insulation.

There are difficulties in attempting to address the extent of damage within a population. The problems often 1) appear late in the service life of building elements, 2) occur within private domains where access is rarely available, 3) occur in inaccessible areas in a building, 4) occur seasonally or at irregular intervals, 5) depend upon the lifestyle of the occupants.

Conduct of the study

It is unwise to expect that the costs of statistically accurate random sampling methods for the US housing population, by climatic regions, will be underwritten. So it is necessary to consider house condition survey methods which are currently in use and to consider the what appropriate conclusions can be drawn from these results.

The data used in this study are contained in 670 home inspection reports of Home Inspection Service (HIS), a private concern which has inspected houses for prospective home buyers in the Champaign/Urbana area from 1980 to the present. The two principal inspectors are Henry Spies, who is publications director for the Small Homes Council, and William Rose, the author of this study. The operation of HIS is in no way associated with the activities of the SHC/BRC.

The function of a house inspection is: 1) to identify damage by location, extent and severity, and, 2) to recommend corrective or preventive measures. Inspection reports were written following house inspections and mailed to clients. These reports contain descriptions of damage and description of corrective or preventive measures. The scope of the analysis is limited by the scope of data included in the inspection reports. The data acquisition methods were outside the control of the study.

The study was designed to find correlations between evidence of damage and evidence of moisture sources. Correlations are not made here between evidence of damage in various building assemblies. Data on individual wall assemblies (in terms of components used and continuity of air and vapor barriers), building age, and "lifestyle" of the occupants, is simply not available in the inspection reports.

There is another potential limitation to the use of inspection reports to estimate damage within a population. It is often charged that inspectors bring predispositions to findings. A recent review of a Swedish moisture survey contained the comment:

"When reports from investigations of building failures were compared, it was found that it was sufficient to read who had carried out the survey to know the cause which would be given in the report. Take for example water penetration in brick joints. Investigator A always looked for leakages in the brick joints and investigator B always looked for ways the water could penetrate joints around windows. As they blindly found what they wanted, different causes were indicated in their reports." (Tolstoy, 1984).

A chi-squared comparison of the reports of Spies and Rose was conducted. The reports of the two inspectors were separated into two distinct data sets. The number of findings by each inspector of total problems among descriptive conditions and explanatory conditions was counted and made into Table 3. A chi-squared analysis was performed. The parameters established were "inspector" and "condition". The null hypothesis was set as--"inspector" parameter is independent of "condition" parameter. An alpha value of .05 was established. $F\text{-alpha} (.05,4)=9.488$. For both inspectors the chi-squared value is less than $F\text{-alpha}$, so the null hypothesis is accepted. The conclusion is that the findings of conditions is independent of the inspector making the findings.

LOCAL CONDITIONS

House Construction

The homes that were studied were between 100 and 2 years old. All the homes used conventional light wood framing techniques typical of the era in which they were built. In the reports done at the time of inspection, the age of the home was not noted and the particular sheathing and siding materials were not identified. This is unfortunate and indicates a limitation on the use of inspection reports for moisture transfer analysis.

Three foundation types were identified--slab, crawl space and basement. Many of the homes studied had a mix of foundation types, for example split- and tri-level homes, homes with partial basements, and homes with additions on a different foundation type. For purposes of this study, such homes were identified as having two foundations and the moisture conditions of each was noted.

The earliest homes in this report were principally on original crawl spaces which were later excavated to full basements. Following WWI, full basements became the norm until the WWII era. At that time, less expensive foundations--slab and crawl space--were introduced and found acceptance. Slab construction

continued until the 60's. Presently most houses are built on crawl spaces, and a small number of others are built with basements.

The use of a crawl space ground cover to prevent evaporation of soil moisture is still not a universal practice among builders. Many other builders ballast polyethylene ground covers with sand or pea gravel. Failure to properly reduce evaporation from crawl spaces is shown in this report to contribute heavily to moisture damage in houses.

Soil Conditions

Prior to settlement, the Champaign/Urbana area was undrained or poorly drained prairie. New drainage patterns have been established, and the area finds itself now on the divide between the Ohio and Mississippi basins. Nevertheless, the topography is flat. Most drainage is artificial.

The soil contains montmorillonite clay in varying concentrations. The clay contributes to deformation and movement of structural elements in contact with the soil. A section of the survey not connected with this study analyzes the occurrence of deformation of basement walls.

Climatic Conditions

A contemporary of Lincoln from Central Illinois described the area as the "hottest coldest wettest driest place on earth". The area has 5600 heating degree-days (65° base). There are periods of high humidity both summer and winter.

INSPECTION METHOD

HIS performs prepurchase home inspections for prospective home buyers. HIS has conducted inspections for about one-fourth of all home purchases made in the Champaign/Urbana area in the last two years. The inspection is conducted in order to establish in detail the structural, mechanical and surface condition of the building. In addition, it serves as a vehicle for familiarizing the buyer with maintenance and operation characteristics of the home.

It is typical practice for a real estate agent to suggest a home inspection to prospective buyers. This practice has been reinforced by recent court decisions (Easton v. Strasburger, CA, for example), which hold that real estate agents are negligent not only if they fail to disclose serious faults in a home, but even if they fail to discover such faults. Buyers who decline the suggestion are typically buyers with much experience in home maintenance and repair.

Guidelines for the conduct of prepurchase home inspections have been described in documents of the American Society of Home Inspectors (ASHI). The inspections conducted by HIS have in general followed those guidelines. The inspection is a visual inspection; that is, there is no disassembly and reassembly of any components of the building. Tools used during the inspection are usually only a flashlight, screwdriver/probe, inspection mirror, and electrical continuity tester. Tools used occasionally, but not typically, include moisture meter, combustion product "sniffer", and blower door. Table 1 describes what is, and is not, inspected.

The inspection usually lasted 1 1/2 hours. Following the inspection a report was written in narrative, paragraph style, and was sent to the prospective buyer. A certain uniformity of form and style in these reports arose over time which facilitated their use as data sources.

The reports contained two kinds of information--description of conditions and recommendations. The description of conditions indicated the location, scope and severity of damage. The recommendations were proposed measures offered to explain, mitigate or prevent the damage. Because the recommendations were often prescriptive (aimed at prevention) rather than explanatory (aimed at establishing cause and effect) their correlation with incidence of damage is not one-to-one. The recommendations overexplain the effects. In most reports, damage is attributed to more than one cause (poor site drainage and air conditioner condensate discharge into a crawl space, for example). Many reports recommend correcting downspout discharge, for example, where no damage to the home is noted.

There are three strategies for mitigating the effects of moisture in a house--source reduction, ventilation, and air/vapor barrier control. The inspection reports emphasize source reduction. The reasons for this are the practicality, dependability and economy of source reduction measures compared to vapor barriers and ventilation. None of the reports recommend retrofit air/vapor barriers.

The reports make various recommendations regarding ventilation of three different locations--crawl spaces, attics and living spaces. The standing (boilerplate) recommendation for crawl spaces was to keep crawl space vents closed for energy efficiency, and to open them only to help evaporate water which accidentally occurs in crawl spaces. With regard to attic sheathing, when the damage condition was "ok" (i.e. no damage), the ventilation rate was presumed to be sufficient; where damage had occurred, the recommendation for enhanced ventilation rates was coupled with the recommendation of source reduction. With regard to living space, recommendations were made to use kitchen and bathroom exhaust fans to avoid excessive buildup of moisture, and their use was explained as a moisture control device. However, no information was available to the inspectors regarding their use by the previous occupants so no correlations could be made between damage conditions (interior wall conditions, especially) and use of exhaust ventilation devices.

The condition of the wall framing members and the wall sheathing is not inspected because such an inspection is necessarily destructive of envelope materials, and is not permitted under ASHI guidelines. Nevertheless, all walls were inspected from the exterior and interior for deformation under axial and lateral loading.

Inspection of condition and performance of the vapor barrier was out of the question because of the lack of dependable inspection procedures. Blower door tests and tracer gas tests were not used. The tests were considered not only too time consuming and expensive, but were also considered to be inconclusive regarding vapor barrier performance.

ANALYSIS

A preliminary data analysis was conducted. The data fields were chosen as a best guess of what data was available in the reports and what field selection would be the most fruitful. Those fields are shown in Table 1. 471 inspection reports were analyzed using these fields. Certain facts became clear from the first analysis:

- insufficient allowance was made for houses with more than one foundation type (i.e. houses with partial basements and tri-levels),
- reports contained insufficient data to justify inclusion certain fields (presence or absence of a vapor barrier, for example),
- the range of moisture sources needed to be expanded to include plumbing problems and air conditioning condensate drains.

In the second analysis, 670 reports were compiled. The additional reports were those of inspections conducted after the first analysis.

Two kinds of condition fields were included in the report --descriptive and explanatory. Descriptive conditions show the effects of water (or water vapor) damage and are derived directly from the damage conditions mentioned in the inspection reports. Explanatory conditions show possible moisture sources and represent the recommendations made in the inspection reports. The selection of fields was refined to create an input form shown in Table 2.

This study was not structured with random sampling of the population of houses in Champaign County. Therefore, this study does not extrapolate the data in this study to the population of homes in the geographic area inspected. The sample is quite large, and so one may or may not be willing to draw conclusions regarding the population from the data presented. This author does believe that the homes inspected do fairly represent the population. Factors which would influence the reader's willingness to extrapolate the findings here would include:

- whether the buyer's choice to have an inspection or not biases the sampling (Realtors contacted all indicate that the range of homes inspected does not differ noticeably from the range of homes sold, or from the range of homes in Champaign County.

- the extent of seller's preparation of the house for sale (Painting of exterior and interior walls can reduce the visible incidence of paint peeling and mildew.)
- willingness of sellers to sell "problem houses".

Besides the damage locations indicated in Table 2, there are other possible sites of moisture damage in a house which are not inspectable during a "visible surfaces" inspection. These would include wall sheathing and wall framing. One conclusion reached in this study is that in the 670 homes, there were no cases of wall failure due to moisture damage. (Failure is defined as the inability to resist gravity and racking loads.) This does not mean that condensation did not occur within wall stud cavities, nor does it mean that walls were free from mildew or from weakened framing members or weakened sheathing. It does indicate that any damage which has occurred in wall stud cavities has not diminished the strength of the walls inspected to the point of crushing or racking failure. (There were 4 houses among those inspected which showed wall failure, but all four failures were due to termites.)

Other possible sites for moisture damage include tub and shower surrounds, and heating and air conditioning equipment. Data on moisture damage to these sites is not part of this study.

REPRESENTATION OF FINDINGS

Descriptive Conditions. The findings of this study are displayed in raw form. There are six sections of findings--

- general condition
- siding condition
- window condition
- floor framing condition
- attic sheathing condition
- interior wall condition

For each section, two charts are presented. The first chart in each section displays the actual number of homes (of 670) which exhibit the individual damage conditions, including the condition "ok". The second chart describes the associations of these damage conditions with explanatory conditions. The results are expressed as percentages--that is the ratio of actual incidences where an explanatory association is present to the number of actual incidences of the damage condition, expressed as a percent.

Explanatory conditions. The following explanatory conditions are used in this report:

- roof leaks--where there is evidence of water penetration through the roof membrane or details, and roof repair is recommended in the report.
- water in foundation--where either dampness or standing water in the basement or crawl space is noted in the report.
- crawl space--where at least part of the house is on a crawl space. The data available distinguishes between crawl spaces with and without ground covers. However, crawl spaces with ground covers tend to show the occurrence of occasional water spotting to the extent that they too have been included as a possible moisture source.
- mechanical source--where a clothes dryer vent, humidifier, or combustion appliance exhaust is noted as contributing to interior humidity.
- evaporative source--where any of the following conditions are noted:
 discharge of rainwater toward the house from downspouts or grading,
 air conditioner condensate discharging into the house
 exposed soil in crawl space
 plumbing leaks which create standing water
 spa or swimming pool.

It can be readily seen that the explanatory conditions overlap--that is, wet or damp foundation, crawl space and evaporative source may all refer to a crawl space without a ground cover. They are to be distinguished as described above.

Conclusions drawn from these charts is described in text in each section.

CONCLUSIONS

Home inspection reports may be used to estimate the incidence of damage conditions in a locality. The benefits which can be obtained from such a survey include:

- reliable estimates of actual occurrences,
- associations with conditions which are damage-inducing,
- criticism of building practice where it is associated clearly with the incidence of damage conditions (e.g., failure to provide a ground cover in a crawl space).

Limitations to the use of inspection reports includes:

- Information is available only on visible surfaces of the homes inspected.
- Identification of causes for individual instances of moisture damage is not possible.
- The selection of inspected homes is not random, so the willingness to extrapolate data to the house population of a region is an individual choice.

5.4% of the home inspected suffer major moisture damage. Another 35% suffer some sort of moisture damage to the visible surfaces, although this damage is often quite minor. Much of the damage noted in these reports occurred in crawl space homes. The damage should be attributed not to crawl space construction, per se, but to the failure to prevent evaporation within a crawl space.

Explanatory conditions have been selected which present clearly the movement of water vapor (not liquid water) in building assemblies. There is a clear association between the presence of evaporative sources of moisture and damage. The evaporative sources noted are concerns of construction practice, not of "lifestyle".

The report of damage conditions and recommendations is reliable and is not greatly influenced by inspector judgment.

Remarks

The American Society of Home Inspectors (ASHI) is the national association which is concerned with the profession of home inspection. This organization has been informed that inspection reports may be of use in compiling moisture damage data for a region. They have promised cooperation in future research, as they expect to gain a comprehensive view from the analysis of their data.

REFERENCES:

Nikolaj Tolstoy, Field investigations of moisture in buildings, National Swedish Institute for Building Research, Third International conference on the durability of building materials and components Volume 2, p 422-432, Technical research centre of Finland, Espoo, Finland 1984.

J. Timusk, Moisture induced problems in NHA housing, Canada Mortgage and Housing Corporation, Toronto, 1983.

American Society of Home Inspectors, Standards of practice, Washington DC, 1981.

INSPECTED	NOT INSPECTED
site drainage soil surface treatment roof attic ventilation gutters and downspouts siding windows and doors attic framing attic insulation wall insulation floor framing foundation appliances electrical system plumbing system heating and air conditioning	wall framing wall sheathing air/vapor barriers infiltration levels "lifestyle"

TABLE 1. INSPECTION AREAS

DESCRIPTIVE CONDITIONS	EXPLANATORY CONDITIONS	SUPPLEMENTARY CONDITIONS
Siding condition ok paint peeling delaminating swelling fiberboard cupped boards nail splitting	Moisture source grading and downspouts condensate c.s. ground cover humidifier clothes dryer unvented combustion plumbing pool or spa	Foundation basement crawl space slab
Window condition ok peeling finish deterioration	Water in foundation ok dampness standing water	Overall condition ok minor moisture damage major moisture damage
Floor framing condition ok signs of condensation mold & mildew structural damage	Roof ok leaks	
Attic sheathing condition ok signs of condensation mold & mildew delamination rotting		
Interior wall condition ok water spotting mold & mildew		

TABLE 2. FIELDS FOR DATA ANALYSIS

DESCRIPTIVE CONDITIONS			EXPLANATORY CONDITIONS		
	no. 1	no.2		no. 1	no. 2
siding condition	9	51	roof leak	16	71
window condition	34	116	water in foundation	68	201
floor framing condition	14	22	crawl space	105	244
attic sheathing condition	12	41	mechanical source	23	74
interior wall condition	15	44	evaporative source	54	194
chi-squared	7.362		chi-squared	8.18	

TABLE 3. FINDINGS OF CONDITIONS BY TWO INSPECTORS

Section 1. SIDING CONDITION

- 9.1% of the homes inspected have siding problems.
- Siding problems are usually associated with the effect of wind driven rain. The correlation of paint peeling with wet foundation conditions and other interior-generated moisture is typical.
- Only 21 homes have reports of paint peeling. Many of the homes inspected were prepared for sale and inspection by recent painting of the exterior.
- Swelling fiberboard is a phenomenon due primarily to the effect of wind driven rain on the exposed down-facing edges of fiberboard siding.
- An association is found between siding problems and crawl space construction. In the inspection reports, siding problems are defined as those which occur on large sections of the siding surface, not in local sites (such as near downspout discharges). Crawl space houses in Champaign County are typically sided very close to the ground (within 4") and local damage to the lower boards is more common than this study indicates.

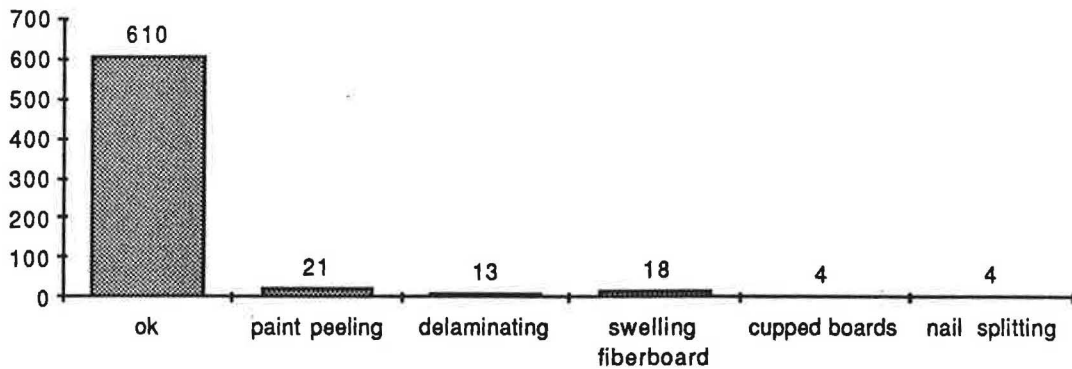


CHART 1.1 NUMBER OF HOMES SHOWING SIDING DAMAGE CONDITION

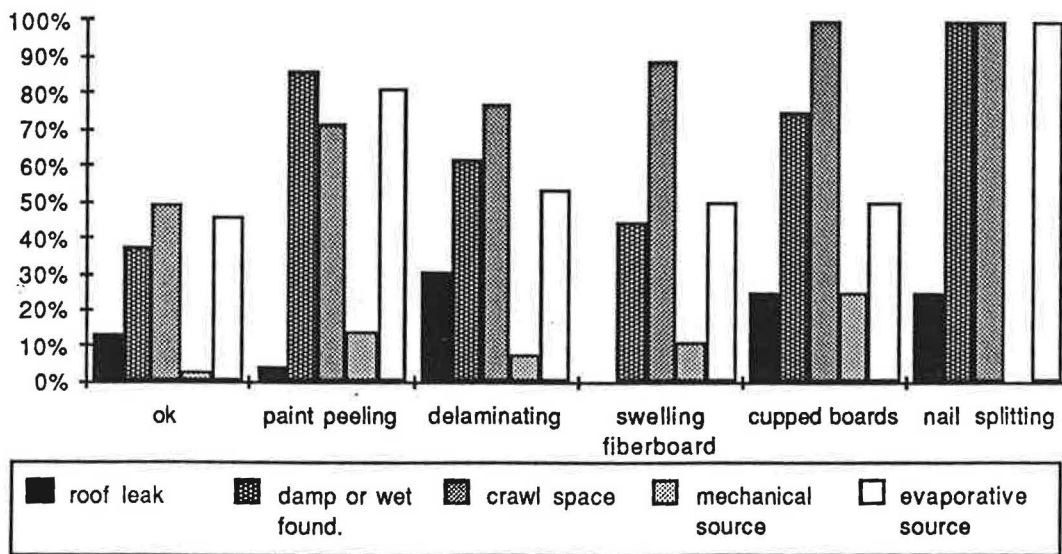


CHART 1.2 CORRELATION OF SIDING DAMAGE CONDITION WITH EXPLANATORY CONDITIONS

Section 2. WINDOW CONDITION

- "Signs of condensation" among descriptive conditions refers to peeling paint and varnish finishes on the interior of windows.
- The sum of the cases does not in this case equal 670, the number of homes inspected. In the analysis a category was established for aluminum frame windows. Such windows are quite common in Champaign Co. (they were a typical detail of National Homes), and the condensation which usually occurred on the frames tended to moisten and soften the sheetrock surrounds. Because the condition is peculiar to one detail they were excluded from this analysis.
- A significant number of windows (5.2%) showed deterioration. There is a slight correlation between deteriorating frames and evaporative sources.

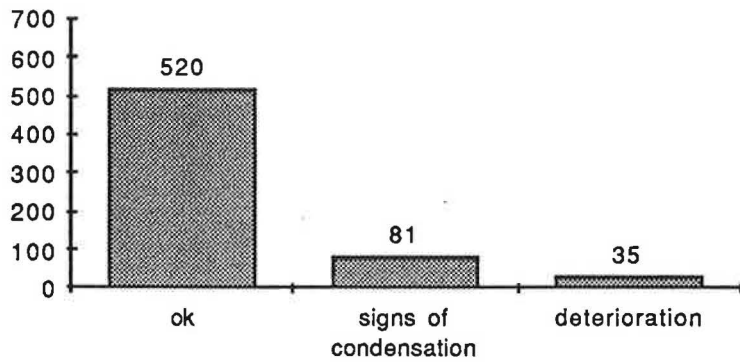


CHART 2.1 NUMBER OF HOMES SHOWING WINDOW DAMAGE CONDITION

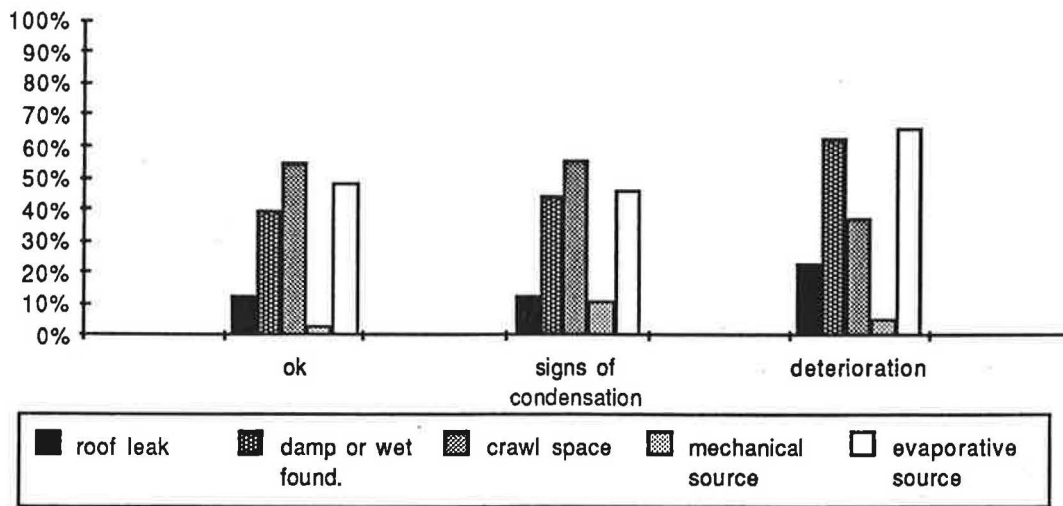


CHART 2.2 CORRELATION OF WINDOW DAMAGE CONDITION WITH EXPLANATORY CONDITIONS

Section 3. FLOOR FRAMING CONDITION

- 5.4% of the home inspected show damage to the floor framing.
- The most destructive damage conditions noted during the inspections were to floor framing elements. The inspectors have noted extreme cases where floor framing members have collapsed into the crawl space after the joist ends had been weakened by fungal growth.
- Damage to floor framing is strongly associated with an evaporative source of moisture in crawl spaces.
- Damage to floor framing occurs first in the band joist and end joist (protected from outside temperatures only by wall sheathing). Damage to this member is included in the damage conditions, although it is structurally less critical than the floor joists--band joists and end joists carry facade loads along their entire length. The damage condition "structural damage" indicates damage to joists such that their load bearing strength is noticeably reduced.
- The asterisk on "structural damage" indicates that this is a major condition requiring replacement or reinforcement of major framing members--floor joists.

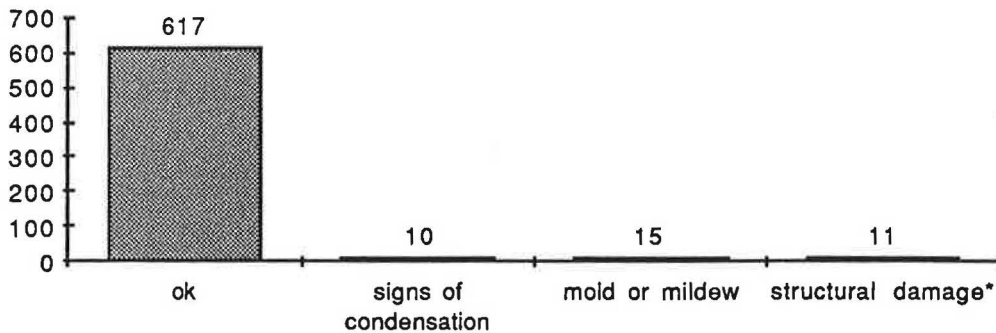


CHART 3.1 NUMBER OF HOMES SHOWING FLOOR FRAMING DAMAGE CONDITION

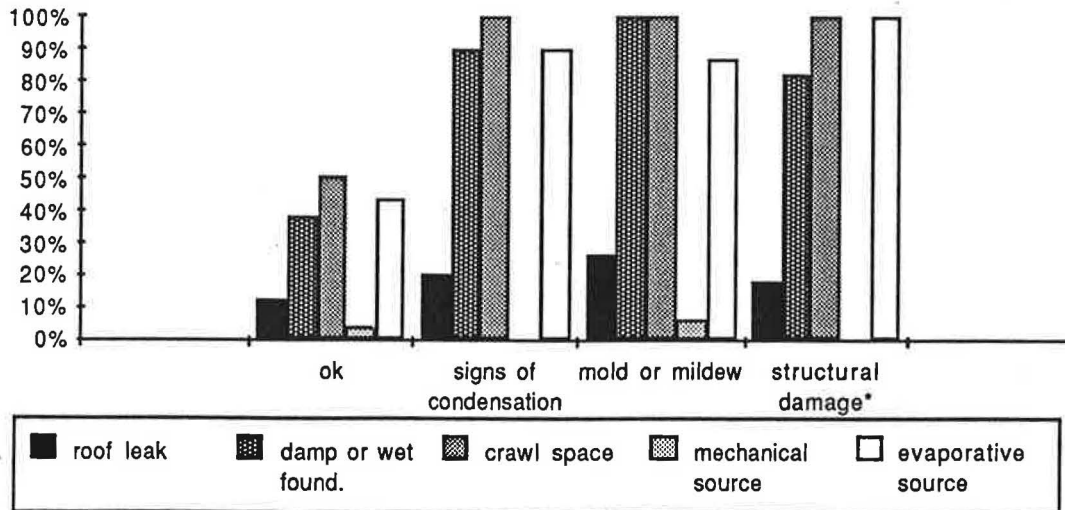


CHART 3.2 CORRELATION OF FLOOR FRAMING DAMAGE CONDITION WITH EXPLANATORY CONDITIONS

Section 4. ATTIC SHEATHING CONDITION

- 8% of the homes inspected suffer damage to the attic sheathing.
- Condensation and mold on attic sheathing is strongly associated with the presence of an evaporative source of moisture and wet foundations.
- Moisture damage can progress from condensation to mold formation to delamination. But a great amount of rotting and delamination of attic sheathing is associated with roof leaks.
- The asterisk on conditions "delamination" and "rotting" indicate that this is a major defect requiring replacement of the sheathing, a structural member.

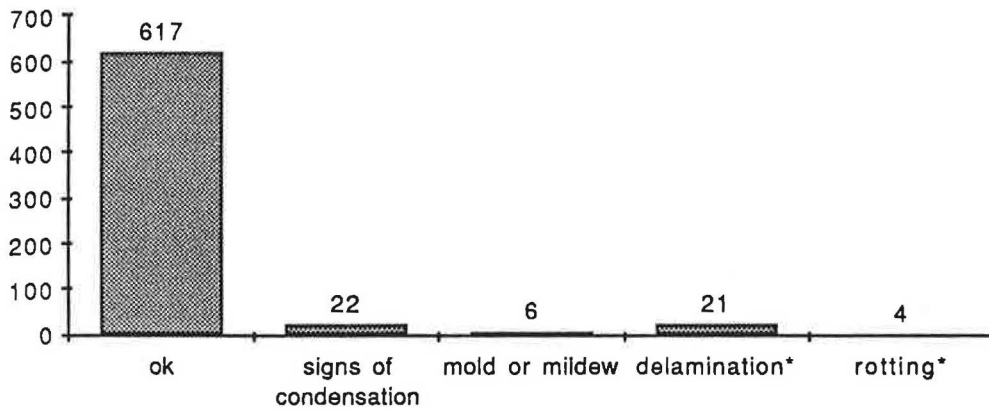


CHART 4.1 NUMBER OF HOMES SHOWING ATTIC SHEATHING DAMAGE CONDITION

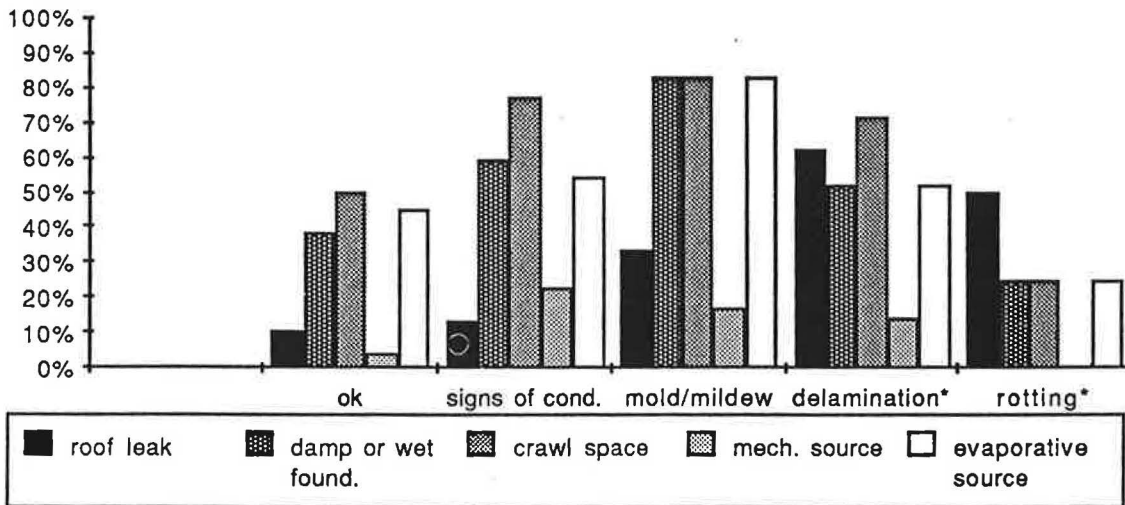


CHART 4.2 CORRELATION OF ATTIC SHEATHING DAMAGE CONDITION WITH EXPLANATORY CONDITIONS

Section 5. INTERIOR WALL CONDITION

- 8.5% of the homes inspected showed water damage to interior walls and ceilings.
- Water spotting on walls (and ceilings) is more often associated with roof leaks than with vapor transfer.
- The formation of mold and mildew on walls is strongly associated with humidity from mechanical sources (dryer vents, humidifiers and unvented combustion appliances).

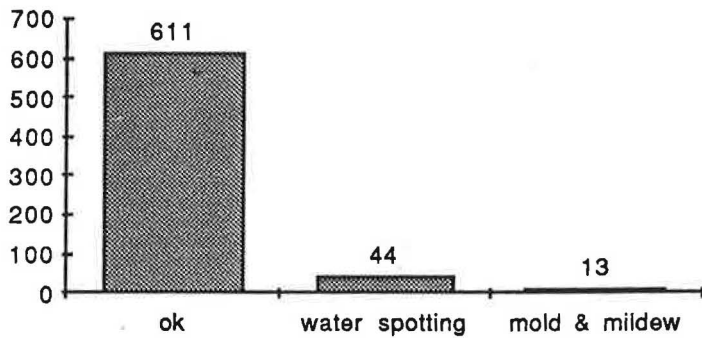


CHART 5.1 NUMBER OF HOMES SHOWING INTERIOR WALL DAMAGE CONDITION

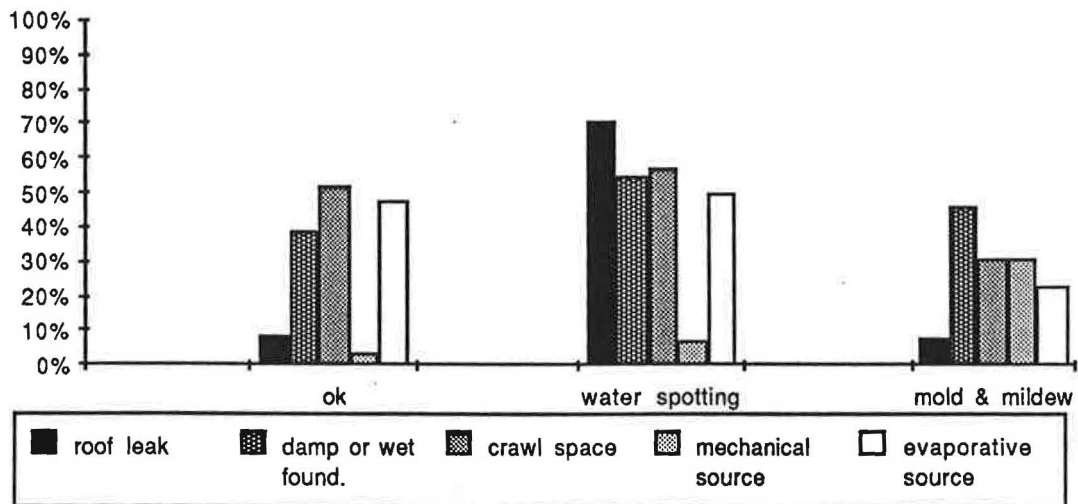


CHART 5.2 CORRELATION OF INTERIOR WALL DAMAGE CONDITION WITH EXPLANATORY CONDITIONS

Section 6. GENERAL CONDITION

- 41% of the houses show water-induced damage; 59% of the homes show no damage at all. The damage note may be very mild (as in the case of peeling of window finishes) to severe, requiring replacement of structural members. Many homes have more than one damage condition.
- 5.4% of the homes inspected have severe moisture damage.
- Three areas most at risk from evaporative-source moisture damage are attic sheathing, floor framing and siding. Of these three, damage to floor framing is most clearly associated with evaporative sources of moisture.
- Crawl space homes have a greater incidence of damage than homes with basements or slabs.

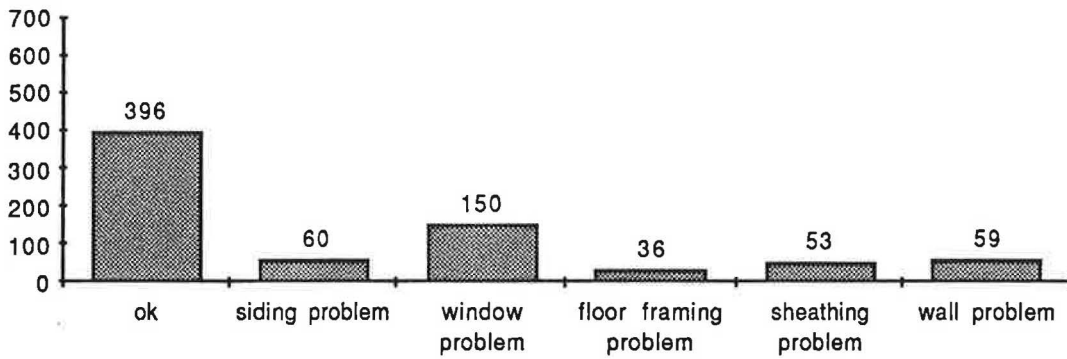


CHART 6.1 NUMBER OF HOMES SHOWING GENERAL DAMAGE CONDITION

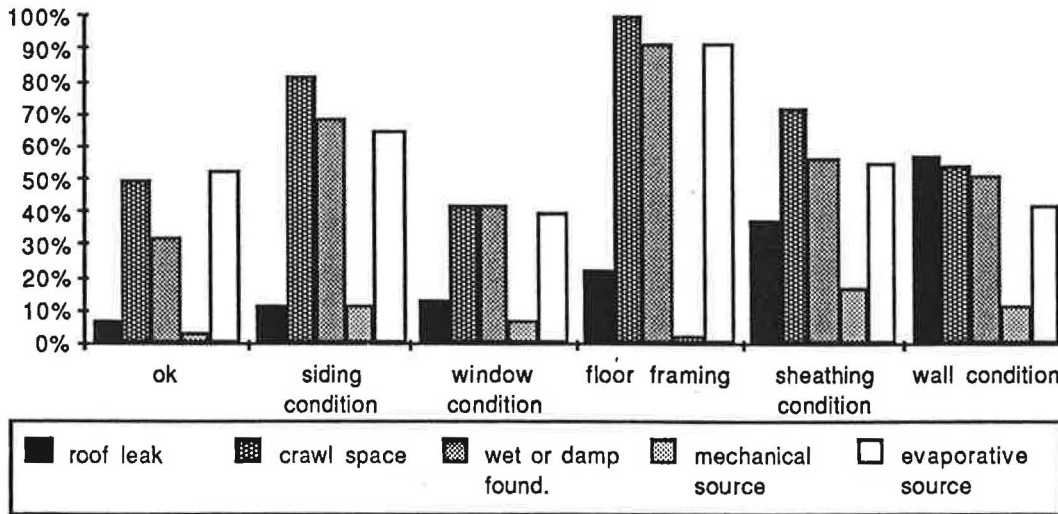


CHART 6.2 CORRELATION OF GENERAL DAMAGE CONDITION WITH EXPLANATORY CONDITIONS