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Assessing Housing Durability: A Pilot Study

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451 7th Street, SW
Washington, DC 20410
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Assessing Housing Durability: A Pilot Study

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by

NAHB Research Center, Inc.
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Foreword

Durability is one of the least understood attributes of the nation's housing stock. Although many attempts have been made to provide solutions to real and perceived durability problems, little has been done to benchmark and monitor the durability of U.S. housing. Such information can provide the proper focus and perspective for improving housing durability while avoiding costly mistakes that may adversely affect the affordability or longevity of homes.

In response to the lack of information, the U.S. Department of Housing and Urban Development commissioned a pilot study of the durability performance of a representative sample of homes in Anne Arundel County, Maryland. This report presents the findings of facts from this pilot study and provides useful criticisms of the study methodology. The study reports several interesting statistics, cause-and-effect relationships, and observations on housing durability. The report also discusses lessons learned from the study with a view toward improved techniques should this effort be expanded to a regional or national level.

The findings of this study not only demonstrate the feasibility of benchmarking and monitoring the durability of the nation's housing stock but also reveal the importance of certain design, construction, maintenance, and environmental factors related to durability. These findings, however, must be tempered with the understanding that they are associated with a relatively small sample in one locality in the United States. The results of this pilot study should not be interpreted beyond the limits of the sampled houses and occupants.

Lawrence L. Thompson
General Deputy Assistant Secretary for
Policy Development and Research

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I. INTRODUCTION

Housing constitutes an essential part of the U.S. infrastructure and economy. For many people, a home is their primary investment and provides the shelter and function needed for a decent "standard of living." Therefore, the durability of residential buildings, including their component parts and materials, is an area that deserves special attention and improved understanding. Unfortunately, little objective or comprehensive feedback information regarding the longevity or service life of existing houses is available to guide decisions that affect the balance between the affordability and durability of future homes. As a result, design and construction decisions regarding durability rely on various forms of experience embodied in standards, building codes, individual builders and designers, manufacturer recommendations, building inspectors, court decisions, and other factors. Without the benefit of a systematic process to obtain objective feedback about actual end-use conditions and the performance of the existing house inventory, trends in design and construction practices affecting durability may tend to drift or not "keep pace" with changes in housing styles, material choices, and owner expectations.

This report presents the findings of a pilot study aimed at developing a reliable and objective means to obtain periodic feedback on the durability performance of the housing stock. The objectives of the pilot study are to

- benchmark the durability performance of a trial sample of the existing housing stock;
- develop and refine a functional method for housing durability assessment;
- determine if the resulting durability assessment data are able to reveal any causal relationships between the condition of a house and various factors; and
- consider practical applications of the study findings.

The pilot study focused on the condition of the exterior envelope for 10- and 30-year-old homes and considers only single-family detached and attached (townhouse) dwellings. The pilot project involved two types of data-collection activities as follows:

- a site condition assessment; and
- a homeowner survey.

The site condition assessment was limited to the characteristics and condition of the exterior envelope of the housing unit, its appurtenances, and the lot. The condition of the interior of the homes and their features were beyond the scope of the study. The homeowner survey, however, addresses both interior and exterior conditions.

Section II of this report describes the data-collection methodology. Section III presents the results from the site assessment and homeowner survey. In particular, Section III provides a combination of anecdotal and statistical findings. Section IV evaluates the durability assessment methodology and recommends improvements. Sections V and VI provide a summary of key conclusions and recommendations resulting from the overall effort.

II. METHODOLOGY

GENERAL

The pilot study focused on the condition of two random samples of single-family homes located in Anne Arundel County, Maryland. One sample consisted of homes in the five- to ten-year-old category and the other on homes in the 25- to 30-year-old category.

The samples were randomly selected by using a GIS-based software package (ArcView) and property tax data obtained from Maryland Property Data, Inc.[1] A total of 211 homes were randomly selected from a population of 185,291 properties in the county. Three units were subsequently disqualified from the study, yielding a total sample of 208 units–103 in the five- to ten-year-old category and 105 homes in the 25- to 30-year-old category. The entire sample of 208 dwellings was retained for statistical analysis. Figure 1 shows the sample region and its geographic distribution.[2]

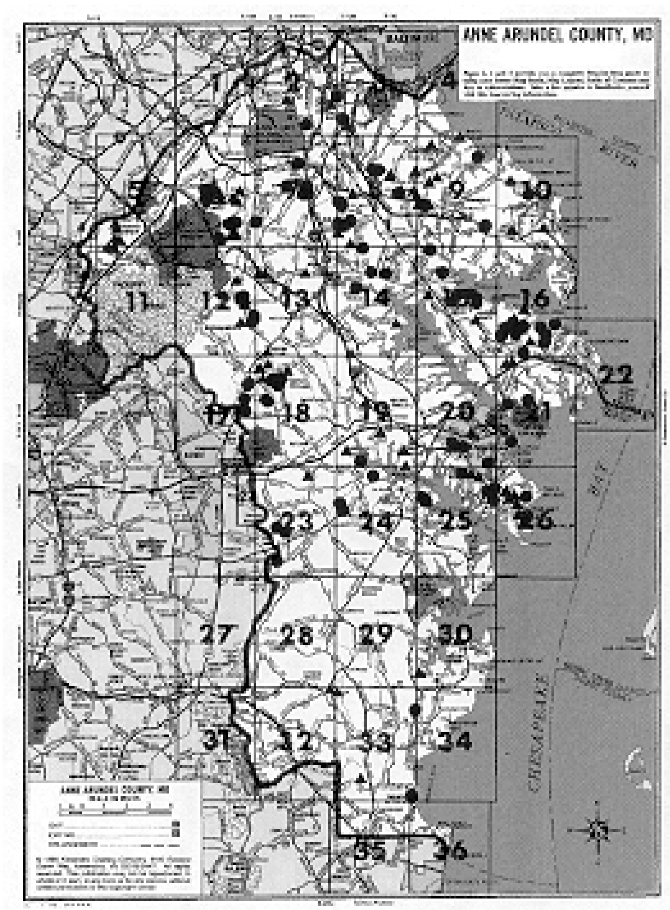


Figure 1
Study sample region.
(Anne Arundel County, MD)

[1]MD Property Data Set, Anne Arundel County, GIS Integrated Solutions, Laurel, MD, March 31, 2000.
[2]Developed using the "ADC Maps on CD" map of Anne Arundel County, Maryland, produced by GIS Integrated Solutions.

The survey method, developed and approved through the Paperwork Reduction Act (OMB #2528-0207), required that a letter be sent to each owner or occupant of the houses in the sample (see Appendix A). The letter explained the purpose of the contact and informed the homeowner or occupant that the home had been randomly selected as a candidate for a site condition assessment. The letter also informed the homeowners that they would be contacted to schedule a site assessment visit and to conduct a telephone survey. A homeowner survey form (see Appendix B) was included with the letter.

SITE ASSESSMENT

The Inspection Form. A site condition assessment form was created for gathering information on a broad range of house and site characteristics and their associated physical conditions. A copy of the site condition assessment form is included in Appendix C. The form used several different methods for entering the required data. For some categories, the inspector entered a "yes" or "no" to signify whether a condition or component was present. For other categories, the inspector checked a single block from among multiple choices. Finally, a 1 to 5 numerical rating was used to rate the condition of the house or component. The numeric score equated to the general condition of the subject component as follows:

1 - Excellent
2 - Good
3 - Adequate
4 - Poor
5 - Needs Repair

In addition, an instructional form given to each inspector provided component-specific guidelines for assigning the numerical scores (see Appendix D).

The use of different methods to record data provided an opportunity to assess the advantages and disadvantages of each method.

The Inspection Team. Five three-inspector teams conducted visual surveys of the exterior of the houses and surrounding site conditions. They recorded selected characteristics of each house and site, assessed the overall condition of the house and various components, and compiled a photographic record. At least one photograph of each house was required. Each inspection team was charged with inspecting roughly 40 houses. At least two members were required to inspect each home and complete separate inspection forms. The use of multiple inspections of selected homes permitted an analysis of consistency in execution of the methodology.

The five teams participated in two calibration exercises. The first exercise was conducted at the beginning of data collection, in part to resolve differences in the application of the form and rating system. Another was conducted at the end of the data collection. The primary goal of collecting the calibration data was to assess the variability in the survey data across individual inspectors before and after the site assessments.

At the completion of the site assessment, the forms for 208 houses were deemed suitable for analysis. The useful response rate varied from question to question due mainly to the presence of conflicting data provided by the inspectors. The conflicting responses were removed from the data reported in Section III. While this procedure resulted in a smaller effective sample size available for statistical analysis, the presence or frequency of conflicting data provided a useful measure of the suitability of various aspects of the data-collection methodology. Appendix E summarizes the raw data as collected.

HOMEOWNER SURVEY

The project team also conducted a telephone survey of homeowners to gather historical information about respondents' homes. The survey addressed sampled a broad spectrum of durability and fitness-of-use issues from the perspective of the homeowners or occupants (see Appendix B for a copy of the telephone survey form).

The homeowner survey form was attached to the homeowner letter mentioned previously; however, only a few homeowners responded. Follow-up telephone contacts improved the response rate, with just short of a 10 percent completion rate achieved. The subsequent site assessment visits provided additional opportunities to increase the survey response rate by permitting inspectors to speak directly with occupants. In the end, the homeowner survey achieved a response rate of 20.7 percent (based on survey forms containing at least partial information).

III. RESULTS

SITE ASSESSMENT

Sample Housing Characteristics

This section presents a discussion of the typical characteristics of the houses in both age-group samples. Each discussion topic is followed by one or more figures (graphs) that complement the text. The study collected a variety of housing characteristic data with the view toward possible explanatory relationships concerning the durability or condition of the sampled homes. It must be noted that the percentages reflected in both the discussion and the graphs are based on sample sizes that vary as explained in Section II, Methodology.

- General

Most of the houses in both age groups were detached (74 percent and 56 percent of the 1970s and 1990s samples, respectively). Two-story structures accounted for most of the homes in both the 1970s (71 percent) sample and the 1990s (81 percent) sample. The orientation (the direction that the front of the house faces) varied greatly in both samples so that no one direction dominated either sample. The most prevalent orientation in the 1970s sample was south (25 percent); in the 1990s sample, it was north (22 percent). The wind exposure of 97 percent of the 1970s houses and 94 percent of the 1990s houses was judged to be a "B" (suburban or wooded exposure) according to ASCE 7 definitions (ASCE, 1999).

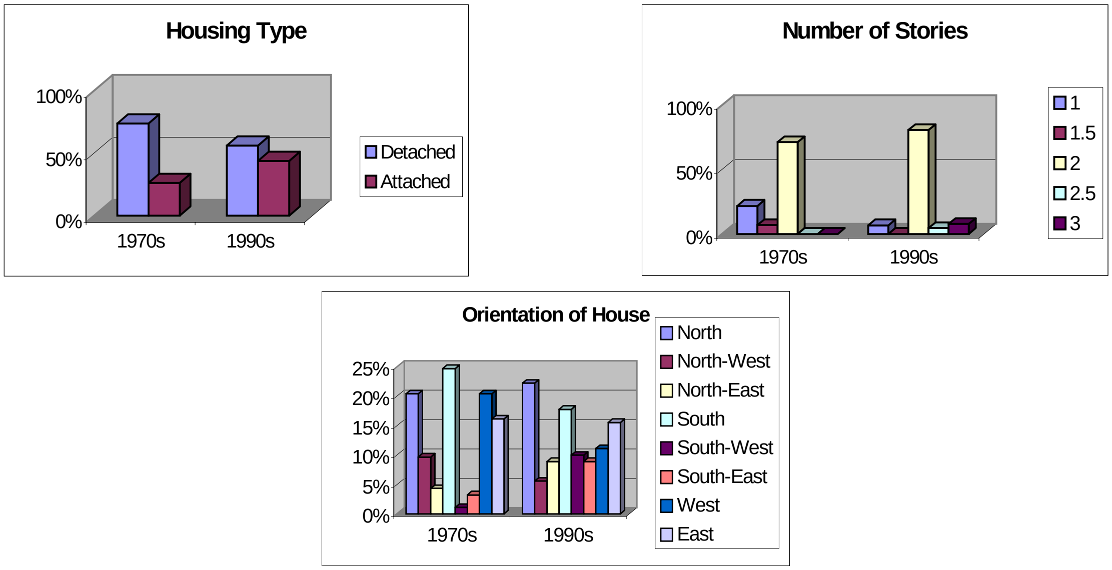


Figure 2
General sample housing characteristics.

⊄# Foundations

Most of the houses in both samples were constructed on basement foundations (57 percent and 78 percent, respectively). Block was the predominant foundation material in the 1970s homes (51 percent), but concrete accounted for the majority of 1990s foundations (73 percent). Seven percent of both samples had window wells, and 1 to 2 percent of the samples had covered wells. Twenty-two percent of the 1970s sample and 21 percent of the 1990s samples had walkout basements. Sixteen percent of the 1970s sample and 19 percent of the 1990s sample had a stairwell.

Figure 3
Foundation characteristics of sampled homes.

⊄# Exterior Finishes

Vinyl siding was the most common siding material in both samples (33 percent and 63 percent for the 1970s and the 1990s, respectively). While aluminum (23 percent) and brick (22 percent) closely rivaled vinyl in the 1970s sample, the 1990s sample contained no close competitors. It appears that the high frequency vinyl siding in the 1970s sample was the result of retrofits; vinyl did not find widespread use in new-home construction until much later. The siding on 59 percent of the 1970s houses and 84 percent of the 1990s houses terminated at least six inches above ground.

Metal was the most common soffit material in both the 1970s and 1990s samples (45 percent and 53 percent, respectively). Wood was the second most common material (40 percent and 24 percent) and vinyl the third most common (13 percent and 22 percent, respectively). Most 1970s houses had an exposed wood fascia (54 percent) while the most common material in the 1990s houses was metal over wood (46 percent). Metal accounted for another 39 percent in the 1970s sample and wood for 41 percent in the 1990s sample. Vinyl followed in both the 1970s and 1990s sample with 6 percent and 11 percent, respectively. Ninety-seven percent of the 1970s homes and 99 percent of the 1990s homes had gutters and downspouts. Aluminum accounted for the majority of gutters and downspouts in both samples (87 percent and 82 percent, respectively). Eighty-two percent of the 1970s homes and 98 percent of 1990s homes had splash blocks.

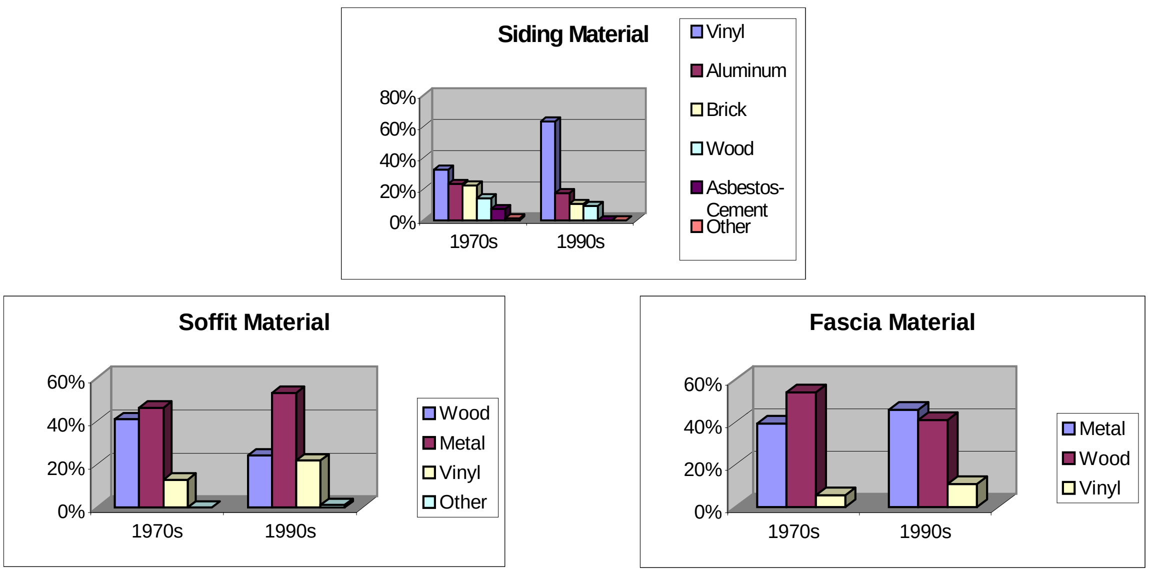


Figure 4
Exterior finish materials on walls and overhangs.

Asphalt shingles (99 percent and 100 percent for the 1970s and 1990s sample, respectively), gable roofs (84 percent and 99 percent), and a slope range of 3 to 6 inches in 12 inches dominated both samples (94 percent and 88 percent, respectively). While overhangs of 6 to 12 inches were the most common in the 1970s sample (26 percent), a variety of larger overhangs were also common (totaling 60 percent). The 6- to 12-inch overhangs (65 percent) were also the most common in the 1990s sample. The size of market share claimed by overhangs in the range of 6 to 12 inches in the 1990s sample suggests a trend away from the larger overhangs of the 1970s.

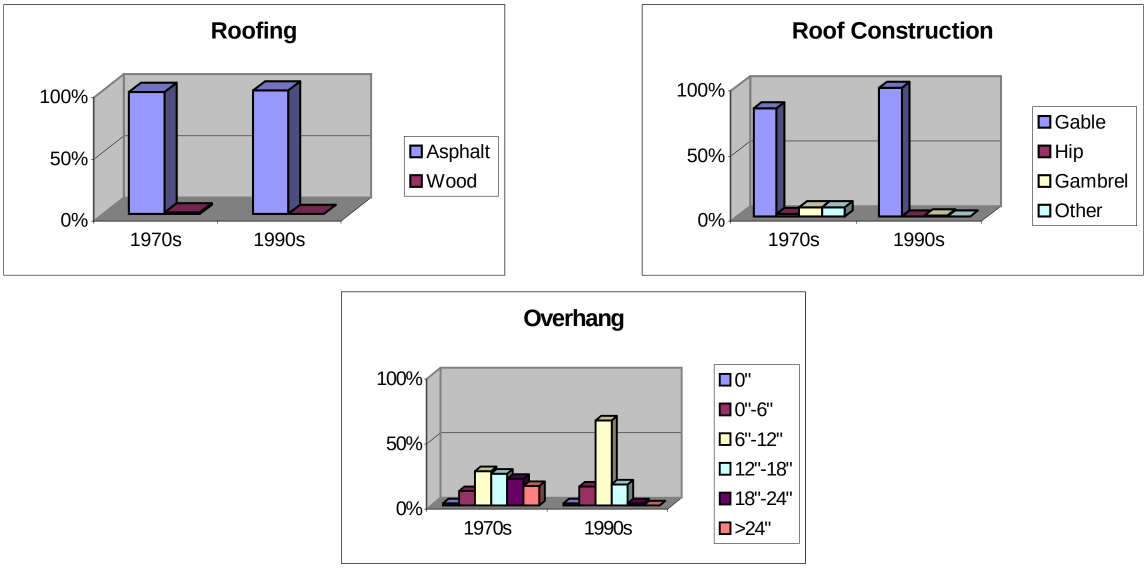


Figure 5
Roof characteristics.

⊄# Windows and Doors

Wood was the most common window frame material in the 1970s sample (40 percent) while most 1990s houses had vinyl windows (65 percent). Double-pane windows were the most common glazing type in both samples (65 percent and 98 percent for the 1970s and 1990s, respectively). Single-pane windows were not uncommon in the 1970s houses (35 percent) but were almost absent in the 1990s sample (2 percent). Most houses did not have storm windows (67 percent and 96 percent for the 1970s and 1990s houses, respectively).

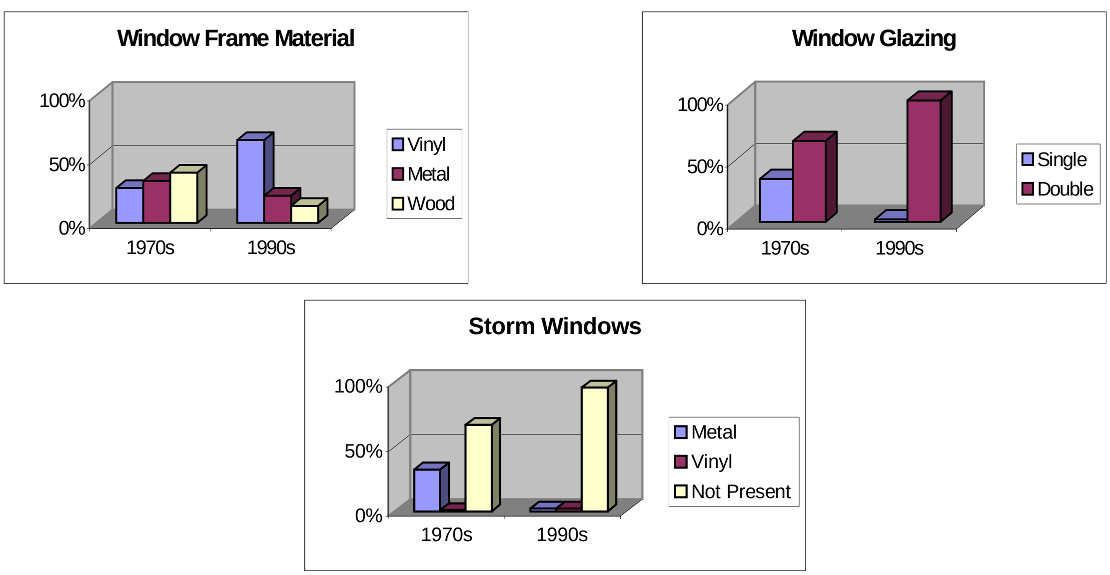


Figure 6
Window characteristics.

Seventy-five percent of the 1970s doors were constructed of wood while metal accounted for 66 percent of the exterior doors in the 1990s. Metal captured the other 25 percent of the 1970s sample. Wood (26 percent) and vinyl (5 percent) accounted for most of the remaining 1990s doors. Twenty-seven percent of the 1970s houses had no storm door, and 59 percent of the 1990s sample had none.

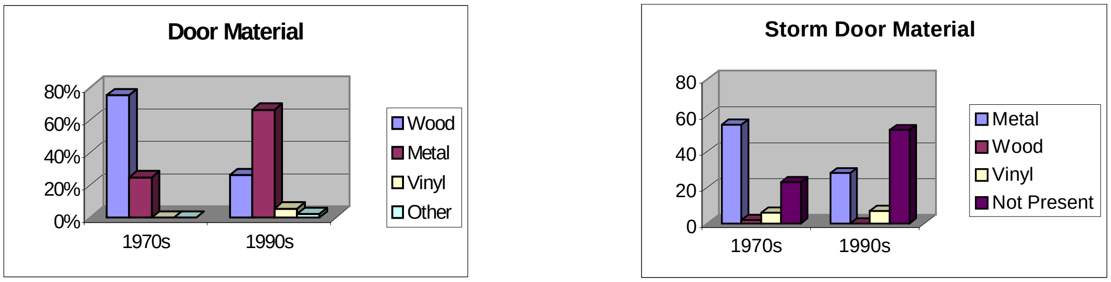


Figure 7
Door characteristics.

- Roof Venting and Penetrations

Sixty-one percent of the 1970s homes made use of gable vents, 61 percent soffit vents and 34 percent ridge vents. Fifty-nine percent were fitted with plumbing vents and 7 percent with fan vents. Thirty-one percent of the 1990s homes used gable vents, 83 percent soffit vents, and 74 percent ridge vents. Forty-nine percent were reported to have plumbing vents penetrating the roof, as observed in the survey.

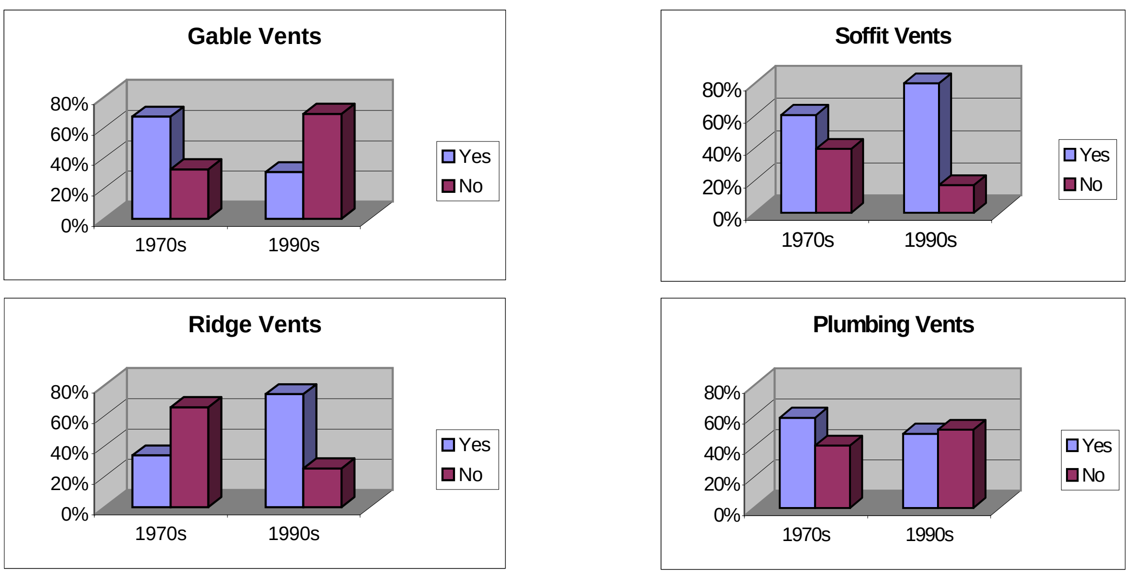
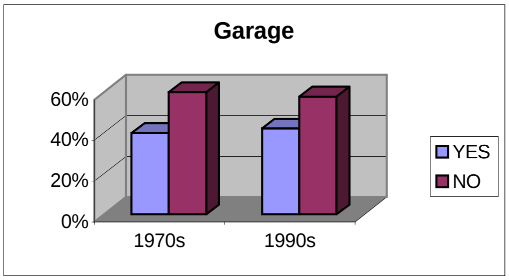


Figure 8
Roof venting and penetrations.

- Appurtenant Structures

Forty-one percent of the 1970s houses had garages as did 45 percent in the 1990s sample. Eighty-six percent of the 1970s garages and 96 percent of the 1990s garages were attached to the housing unit.



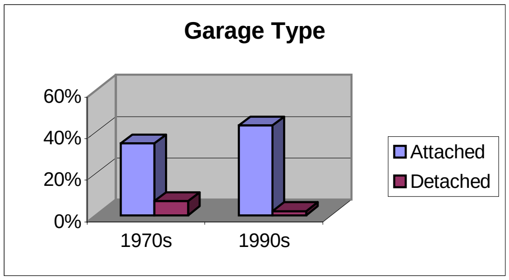
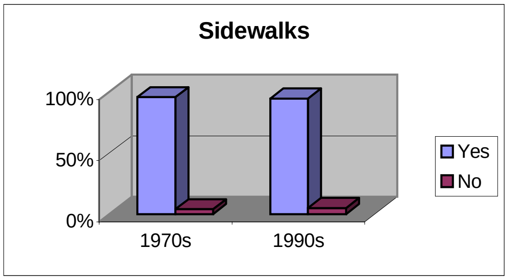


Figure 9
Garage characteristics.

Almost all houses in both samples (96 percent and 95 percent of the 1970s and 1990s samples, respectively) had sidewalks. Ninety-six percent and 97 percent of the 1970s and 1990s sidewalks, respectively, were impervious (e.g., concrete or asphalt). Approximately 98 percent of both samples had driveways. Ninety-five percent of the drives in both samples were impervious.



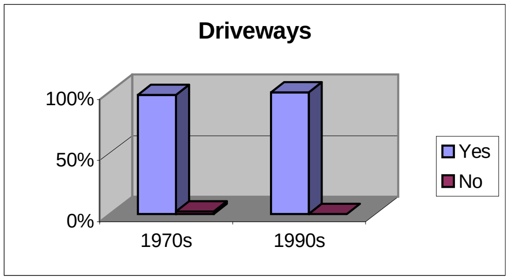


Figure 10
Sidewalk and driveway data.

Forty-three percent of the 1970s homes had decks as compared with 68 percent of the 1990s sample. Ninety-three percent of the 1970s decks and 96 percent of the 1990s decks were constructed of treated wood. Ninety-eight percent of the 1970s decks and 92 percent of the 1990s decks were surface nailed. Two-thirds of the 1970s houses were on fenced lots while only 44 percent of the 1990s houses were likewise on fenced lots.

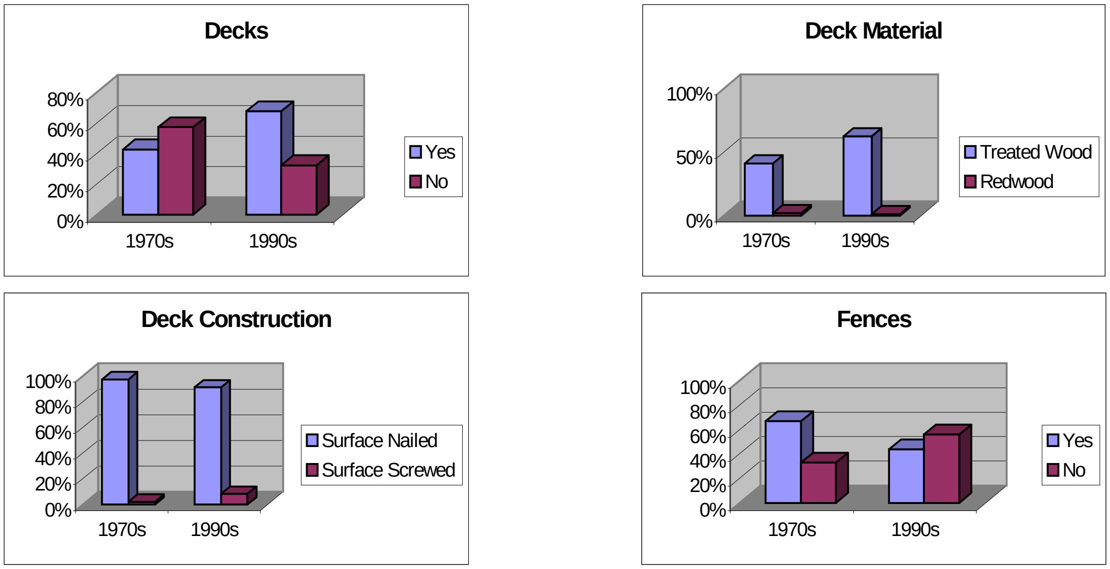


Figure 11
Deck characteristics.

⊄# Landscaping

Ninety-three percent of 1970s houses and 95 percent of 1990s houses had landscape plants within 10 feet of the structure. The most common landscaping features adjacent to the 1970s homes were large shrubs (83 percent), flowerbeds (81 percent), and wood mulch (62 percent). The most common landscaping features of the 1990s homes were flowerbeds (90 percent), wood mulch (84 percent), and large shrubs (52 percent). In all, 9 percent of the 1970s houses and 8 percent of the 1990s houses were sited on lots with retaining walls.

Condition Assessment

This section presents a summary of the results of the visual assessment of both housing sample age groups. The assessment is based on both quantitative and qualitative measures of the state of the houses and their components. As with the data in the Housing Characteristics section, the sample size discussed in this section varies by component due to the elimination of conflicting inspection results. Please refer to Appendix E for comprehensive tabulations of data from the visual survey. In addition, the photographic record of this section provides illustrations of various observed conditions.

⊄# Site Grade and Drainage

The occurrence of surface depressions accounted for almost twice the share of houses in the 1970s sample compared with the 1990s sample (20 percent vs. 11 percent). Surface depressions are indicative of poor site drainage that may be associated with durability concerns such as cracked foundations (e.g., settlement) or water intrusion in basement foundations. The Causal Relationship discussion explores the impact of site and exterior envelope characteristics such as surface depressions on the condition of the exterior of the home. This study did not consider the connection between exterior and interior conditions.

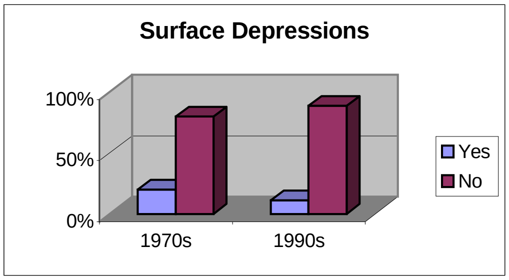


Figure 12
Frequency of surface depressions observed on sampled sites.

∉# Foundation Cracks

While most visually detected cracks were small, the study made no measurements. Visible cracks occurred in 34 percent of the 1970s sample and 19 percent of the 1990s sample. The occurrence of foundation cracks, while not always a significant structural problem, may indicate differences in foundation performance associated with material selection and site conditions, among other factors considered later in this section.

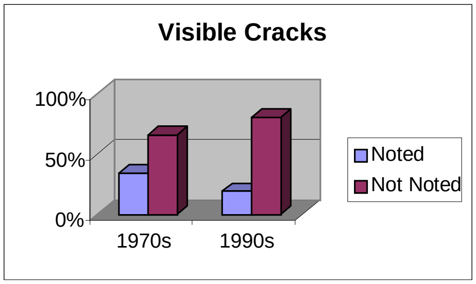


Figure 13
Frequency of observed foundation cracks on sampled homes.

∉# Rot

Any detected rot resulted in a positive response on the survey form. Rot commonly occurred in exterior wood trim components and usually appeared to be localized in nature. Thirty-one percent of the 1970s homes and 22 percent of the 1990s homes were noted as exhibiting some rot.

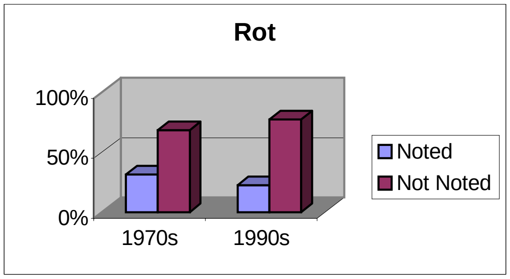


Figure 14
Frequency of observed rot in sampled homes.

⊄# Insect Damage

Three percent of the 1970s houses were reported to have visual signs of insect damage compared with only 1 percent of the 1990s houses. Inspectors noted termite drill holes at two 1970s houses and carpenter bee boring holes at another. No specific insects were mentioned for the 1990s houses.

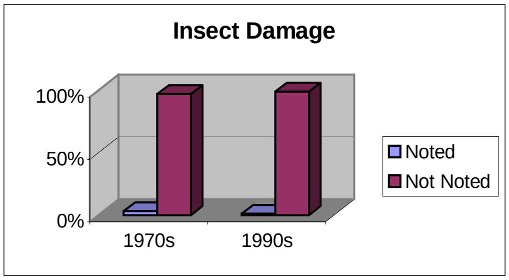
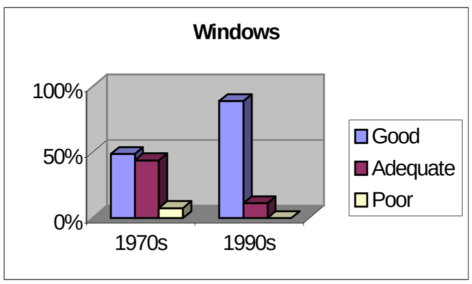


Figure 15
Frequency of observed termite damage.

⊄# Windows

This and later sections use qualitative ratings to describe the condition of components as judged by the inspectors. A "good" condition generally signified little sign of wear and tear and complete function. "Adequate" may be interpreted to mean that the component was judged to be functional with reasonable signs of wear and tear. A rating of "poor" is associated with some loss of function. Windows tended to be rated in good condition in both samples (49 percent of the 1970s houses vs. 89 percent of the 1990s houses). For the 1970s houses, a substantial share (44 percent) had windows judged to be adequate. Eight percent of the 1970s windows were rated as poor, but none of the 1990s windows rated that low. Most storm windows in the 1970s sample (53 percent) were judged to be in adequate condition, although the vast majority of the 1990s storm windows (79 percent) were in good condition.



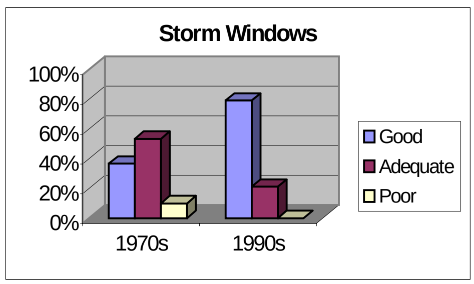


Figure 16
Window condition ratings of sampled homes.

⊄# Doors

The inspectors rated the doors in 54 percent of the 1970s houses and 89 percent of the 1990s houses as good. Another 40 percent in the 1970s houses and 11 percent in the 1990s houses earned a rating of adequate. Six percent of the 1970s houses had doors that were rated poor. Most storm doors in both the 1970s and 1990s sample (56 percent and 87 percent) were rated good by the inspectors.

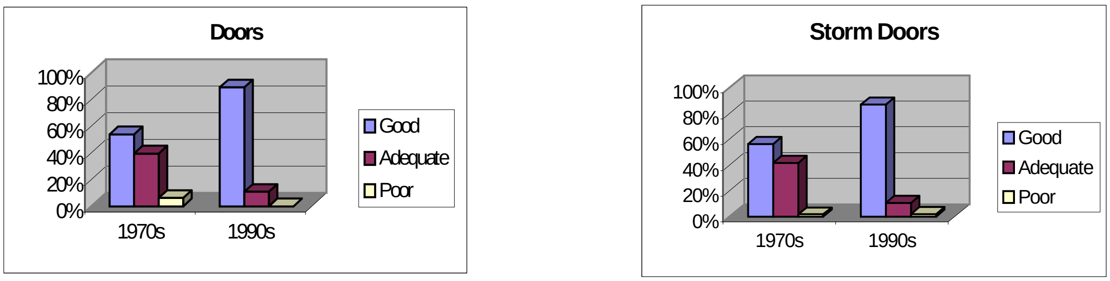


Figure 17
Door condition ratings of sampled homes.

⊄# Fascia

The fascia on the 1990s houses were mostly in good condition (58 percent) while the fascia on the 1970s sample houses were typically in adequate condition (51 percent). Another 39 percent of the fascia on 1970s houses were judged by the inspectors to be in good condition, and an additional 15 percent of the 1990s houses were rated adequate.

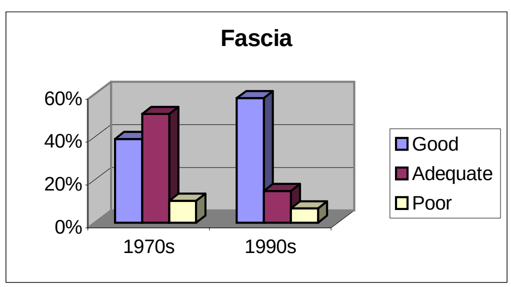


Figure 18
Fascia condition ratings.

⊄# Roof

Both roof valleys and roof openings[3] in the 1990s (88 percent and 71 percent, respectively) sample tended to be in good condition by a wide margin. Most of the 1970 houses were graded adequate for roof valleys and roof openings (52 percent and 60 percent, respectively). With exterior inspections from the ground only, it is difficult to assign a quantitative measure to these ratings. However, the homeowner survey offered some insight into water leakage problems that may be associated with these and other construction features (see Homeowner Survey).

[3]The term "opening" is meant to signify any penetration of the roof to accommodate mechanical and plumbing vent requirements.

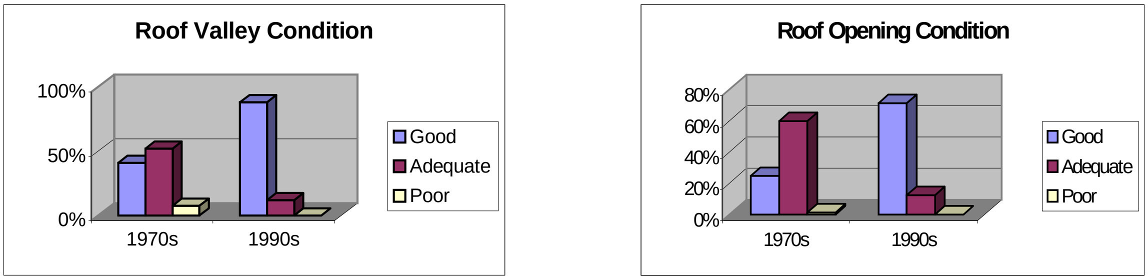


Figure 19
Condition ratings of roof features.

⊄# Exterior Appurtenances

Exterior stairs were most commonly rated good in the 1990s sample but only adequate in the 1970s sample. Cracking and signs of settlement were common factors that resulted in poor ratings for exterior stairs in relatively few homes. The majority of patios (57 percent) and decks (56 percent) in the 1970s sample were graded adequate while the 1990s patios (71 percent) and decks (67 percent) were judged to be typically in good condition. Porches, on the other hand, were typically rated adequate in both the 1970s and 1990s samples (70 percent and 75 percent, respectively).

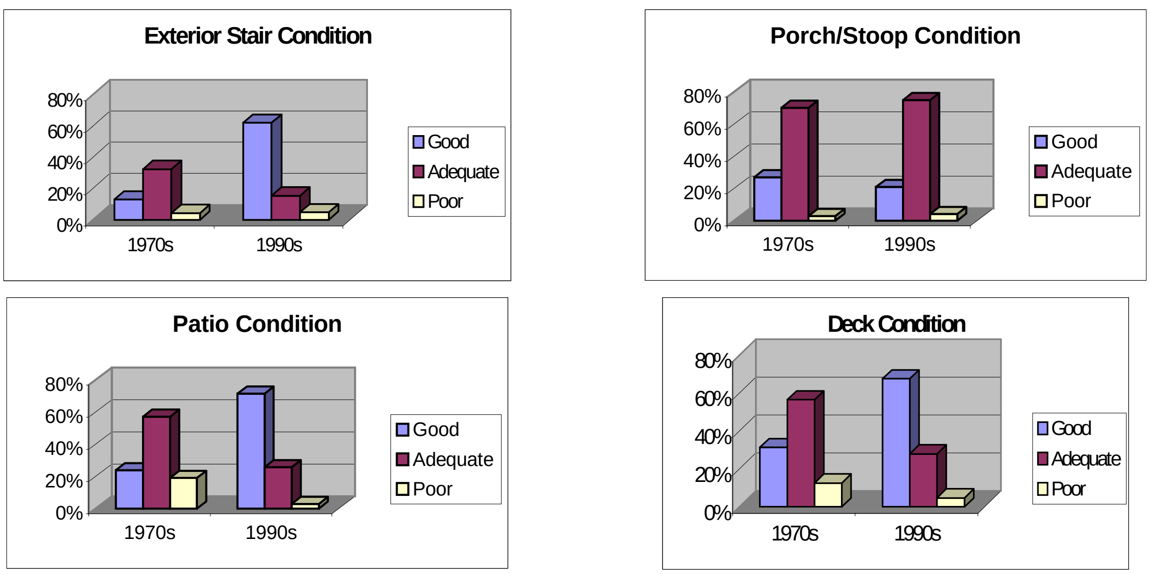


Figure 20
Ratings of exterior stair, porch, patio, and deck condition.

Inspectors rated the fences of 56 percent of the 1970s houses as adequate and 56 percent of the 1990s fences as good. Thirty percent of the 1970s fences were rated to be in good condition while 38 percent of the 1990s fences were judged to be in adequate condition.

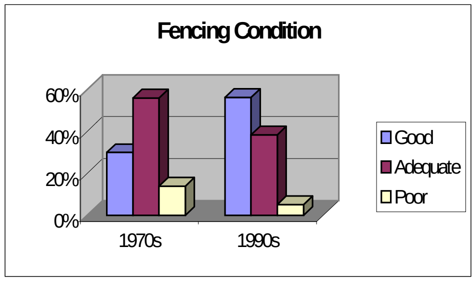


Figure 21
Rating of fencing condition.

Scoring

Each inspector was required to record four scores for each component of every house, one score for each orientation or side of the house–front, left, right, and rear (see survey form in Appendix C). A mean score for each component-orientation combination was developed for each house by averaging the scores of the inspectors. The resulting mean score of all of the houses was then averaged for each component-orientation category. Appendix E presents the results. The four orientation-category scores served as the basis for developing an overall average score for each component in the 1970s sample, the 1990s sample, and the total sample. Table 1 presents the results.

TABLE 1
AVERAGES OF BUILDING COMPONENT CONDITION RATINGS

BUILDING COMPONENT CONDITION VISUAL SURVEY RESULTS			
	1970s	1990s	Total Sample
Grading	2.29	2.22	2.25
Landscaping	2.79	2.52	2.66
Sidewalk	2.80	2.27	2.58
Foundation	2.61	2.14	2.37
Porch	2.86	2.52	2.71
Deck	2.99	2.83	2.90
Siding	2.70	2.33	2.51
Door	2.74	2.21	2.47
Windows	2.77	2.20	2.48
Trim	2.93	2.63	2.78
Openings	2.91	2.62	2.76
Soffits	2.71	2.28	2.48
Fascia	2.92	2.50	2.70
Gutters	2.84	2.40	2.60
Flashing	3.07	3.18	3.13
Roof	2.72	2.19	2.43
Caulk	3.34	3.02	3.20
Paint	3.00	2.46	2.77

Scores between 1 for excellent and 5 for needs repair are possible, but the average scores in the table fall in a more narrow range between 2.14 and 3.34 (i.e., between good and adequate). While the difference between the 1970s scores and the 1990s scores may be small, no statistical analysis was performed to determine whether any of the 1970s data sets differ statistically from their 1990s counterparts. The reservations concerning the scoring data expressed in Section IV of this report bring into question the value of such an analysis. Nonetheless, the data in Table 1 offer some useful insights.

- With the lone exception of flashing, the 1970s sample scores are higher (worse) than the 1990s scores.
- The caulk-related scores were worse than the average of overall scores in both age groups.
- Windows, doors, roofs, and the paint on window frames, soffits, and siding were among the components in the 1970s sample that fared the worst proportionately when compared with the 1990s sample.
- Siding, trim, and fascia were among the components in the 1970s sample that did not fare as poorly when compared proportionately with the 1990s sample.

Table 2 presents the coefficients of variations for each of the scored components. In half of the categories, the variation in the ratings for the 1990s sample is greater than that for the 1970s sample, suggesting that the assessed conditions tended to vary similarly in both age groups. Some additional observations include the following:

- All of the paint and caulk category ratings varied more proportionately in the 1990s sample than in the 1970s sample.
- The condition rating of windows, doors and roofs showed more relative variation in the 1970s sample than in the 1990s sample.
- Siding, trim, and fascia in the 1990s category showed more rating variation than the 1970s sample.
- The component with greatest variation in overall rated condition was grading.

Causal Relationships

Based on the housing characteristic and condition data presented in the previous sections, the study explored several possible cause-and-effect relationships to explain the data more fully.

Typically, the methodology involved the use of contingency tables to classify the houses in the survey in accordance with some construction characteristic and some housing condition. To illustrate the approach, Table 3 presents the contingency table that was used to examine the role of foundation material in the occurrence of visible foundation cracks.

TABLE 2
COEFFICIENTS OF VARIATION FOR BUILDING COMPONENT CONDITION RATINGS

BUILDING COMPONENT CONDITION VISUAL SURVEY RESULTS			
Coefficients of Variation			
	1970s	**1990s**	**Total Sample**
Grading	0.53	0.48	0.51
Landscaping	0.25	0.24	0.25
Sidewalk	0.37	0.32	0.38
Foundation	0.26	0.30	0.30
Porch	0.19	0.33	0.26
Deck	0.26	0.31	0.29
Siding	0.27	0.29	0.29
Door	0.31	0.27	0.31
Windows	0.27	0.22	0.28
Trim	0.23	0.29	0.27
Openings	0.25	0.29	0.27
Soffits	0.27	0.24	0.27
Fascia	0.25	0.37	0.32
Gutters	0.30	0.25	0.29
Flashing	0.38	0.33	0.36
Roof	0.28	0.25	0.29
Caulk	0.28	0.39	0.35
Paint	0.24	0.33	0.30

TABLE 3
2X2 CONTINGENCY TABLE:
VISIBLE CRACKS IN FOUNDATIONS VERSUS FOUNDATION MATERIAL

	BLOCK	CONCRETE	TOTAL HOUSES
Has visible cracks	35	9	44
Has no visible cracks	19	83	102
Total Houses	54	92	146

The data in the contingency table were then subjected to a statistical analysis tool called a Chi-square test. This procedure determines whether it is likely that the two groups of houses differ (in a statistical sense) in terms of the proportion that evidence a given condition, for example, the presence of foundation cracks. A confidence level of 95 percent was used for all such comparisons.

A discussion of the findings of the analysis follows (see Appendix F for a more in-depth discussion of the statistical analysis).

∉# Foundation Material versus Foundation Cracks

A statistical analysis of the survey data indicated that foundation type is a factor in the occurrence of visible foundation cracks. Foundation material and the methods used with each material seem to play a role. Examination of the survey data reveals that 65 percent of block foundations have visible cracks while only 10 percent of concrete foundations have visible cracks.

An examination of the data revealed that about two-thirds of houses with block foundations were built in the 1970s. Further analysis of the data indicated that the 1970s houses have a higher proportion of visible cracks. These findings brought into question whether time or foundation material was the real factor. Since most house foundations built in the 1970s are block foundations, does it merely appear that block foundations tend to have more cracks? A separate analysis of the foundation material and visible foundation crack data was performed for each age group. The results for both groups indicated that the occurrence of cracks is not independent of the type of foundation material. So, while time may be a factor in the occurrence of visible foundation cracks, block foundations appear to be associated with a higher proportion of cracks.

∉# Site Condition versus Foundation Cracks

A similar analysis sought to test for a relationship between the presence of surface depressions on a site and the occurrence of visible foundation cracks. The results did not support the proposition that they are unrelated; therefore, it appears that surface depressions also play a role in the occurrence of visible foundation cracks. In the study sample, the 28 percent of the sites with surface depressions accounted for 44 percent of the sites with cracked foundations

∉# Wood Rot

A similar analysis focused on wood rot and the presence of housing characteristics that may be associated with rot, such as the age of the house and the size of the roof overhang. Statistical tests did not indicate that any of these factors play a role in the occurrence of rot. However, these results are believed to point to factors other than a lack of physical cause.

Several factors, including remodeling, may have played a role. Casual observations by the inspectors indicated that many of the houses built during the 1970s were resided. Exterior trim, including soffit and fascia, had been replaced or covered with aluminum or vinyl sheathing. A similar situation was noted with the windows. These observations are confirmed by the graphs of siding and window frame materials on houses built in the 1970s (see Sample Housing Characteristics). Older houses with vinyl siding and vinyl window frames were probably retrofitted since these materials were not commonly used in the early to mid-1970s. Assessment of the condition of covered original materials was usually not possible.

∉# Housing Orientation Analysis

Additional analyses attempted to associate differences in the orientation of the house with siding, paint, and front-door caulk problems, using numerical scoring data from the visual survey of building components. This effort failed to yield meaningful results. Since the results of the condition-rating component of the survey form was used for this analysis, the lack of a statistically valid relationship may likely be associated with a lack of precision in the execution of the rating methodology by the inspectors.

Photographic Record

This section provides photographs of various observed conditions of the sample homes and sites. The photographs are intended to convey the rating system as applied by the inspectors in completing the survey form. Items that did not require a rating (e.g., the presence of foundation cracks or surface depressions on the site) are also illustrated.

∉# Site Grade and Drainage

Figure 22 provides an example of good site grade and drainage as rated by the field inspectors. In this case, the grade is sloped away from the house on all sides. Figure 23, by contrast, shows small surface depressions next to the foundation at the air-conditioner compressor units and where the trash cans are stored. In this case, the site drainage was rated as poor by the field inspectors. In addition, the existence of surface depressions was recorded on the survey form.

Figure 22
Example of good rating for site grade and drainage.

Figure 23
Example of poor rating for site grade and drainage.

∉# Foundation Cracks

When observed, the existence of foundation cracks was also recorded on the survey forms for each sample house. Figures 24 and 25 illustrate typical cracks found in concrete and masonry foundations.

Figure 24
A typical small crack found in a concrete foundation wall.

Figure 25
A typical small crack found in a masonry foundation wall.

⊄# Rot

As shown in Figures 26 and 27, the nature of observed rot was similar in the 1970s and 1990s sample houses. Rot of the exterior woodwork was commonly found on wood or wood composite doors, trim, and siding. Aside from the general vulnerability of untreated wood to decay, rot was often localized at end joints in trim and siding as shown in Figures 28 and 29. Rot was also associated with trim details that trap moisture (see Figure 30). Wood decay was also found on doors, particularly garage doors with wood composite sheathing as shown in Figure 31.

Figure 26
Rot at the bottom of a door frame in a 1990s sample house.

Figure 27
Rot at the bottom of a door frame and trim in a 1970s sample house.

Figure 28
Rot in exterior wood trim of a 1990s sample house.

Figure 29
Rot at the bottom of wood panel siding (insufficient ground clearance) in a 1970s sample home.

Figure 30
Rot in wood trim associated with poor detailing (i.e., lack of cap flashing) and maintenance in a 1990s sample home.

Figure 31
Rot of wood composite panel on a garage door (1970s house sample).

⊄# Windows and Doors

While most windows and doors were rated as good or adequate in the sampled homes, Figures 32 through 35 depict examples of poor ratings. Causes of a poor rating included abnormal wear and tear, broken glazing, and condensation inside double-pane windows.

Figure 32
Abnormal wear and tear on a wood window as an apparent result of pet scratching.

Figure 33
Broken window pane on second-story window.

Figure 34
Condensation inside double-pane windows.

Figure 35
Abnormal wear and tear on a wood door as an apparent result of pet scratching.

∉# Fascia, Eaves, Soffits, and Guttering

Roof fascia, eaves, soffits, and guttering exhibited several problems. In some cases, possible rot or other signs of durability problems were concealed from the view of inspectors as shown in Figure 36. Figure 37 shows the fascia of a 1970s sample home that was rated adequate but was in need of minor repair and maintenance. In this case, the condition of the wood fascia material was sound.

Figure 36
Example of aluminum fascia covering older fascia material on a 1970s sample house (rated good by inspector).

Figure 37
1970s sample house with wood fascia needing minor repair (rated adequate by inspector).

Figure 38 shows that the wood fascia of a 1970s townhouse was also subject to rot at end joints at the brick party wall. Figures 39 and 40 illustrate a failed gutter and damaged soffit for two 1970s sample homes. Other problems with gutters are shown in Figures 41 through 45.

Figure 38
Fascia with a poor rating due to signs of rot and paint failure at butt joint to a party wall on a 1970s townhouse sample.

Figure 39
Failed gutter and signs of water damage to soffit on a 1970s duplex house sample.

Figure 40
Failed guttering and signs of water damage on wood fascia underneath aluminum fascia cover (1970s house sample). Note paint failure on window frames.

Figure 41
Vegetation growing in poorly maintained gutter.

Figure 42
Failure to maintain outfall of gutter downspout. Note that wood panel siding does not have sufficient ground clearance.

Figure 43
Damaged downspout (same house in Figure 42).

Figure 44
Sagging gutter.

Figure 45
Rusting party wall cap flashing and damaged gutters.

- Roof and Roofing

Figures 46 and 47, respectively, show typical examples of adequate roofs for 1970s and 1990s house samples. Examples of poor roofing ratings are illustrated in Figures 48 and 49. The tell-tale sign of poor roof shingle condition was the "curling" of shingle tabs. Figure 48 also illustrates improper valley flashing (receiving a poor rating) and buckled roof sheathing.

Figure 46
Example of a 1970s house sample with roofing rated as adequate.

Figure 47
Example of a 1990s house sample with roofing rated as adequate.

Figure 48
A 1970s house with a poor roof based on improper valley flashing and curled shingle tabs on the left roof surface.

Figure 49
Poor roofing rating due to curled shingle tabs (1970s house sample).

⊄# Exterior Appurtenances

This section addresses porches, decks, and sidewalks. Figures 50 and 51 show the porches of two 1990s and 1970s sampled homes that were rated as good. In each case, the porch floor was concrete and wood, where used, was adequately protected from weather and moisture. However, wood deterioration was evident on the porches of the 1970s and 1990s house samples as shown in Figures 52 and 53, respectively.

Figure 50
Porch with good rating (1990s house sample).

Figure 51
Porch with good rating (1970s house sample).

Figure 52
Rot in a wood picket on the porch of a 1970s sample home (one picket has been replaced with treated wood).

Figure 53
Wood floor boards under the porch roof of a 1990s house sample show signs of deterioration.

Figures 54 and 55 show typical decks with a good rating. Unfortunately, the photographic record does not include usable pictures of decks in poor condition for purposes of contrast.

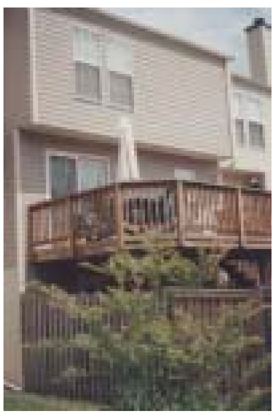


Figure 54
Example of a wood deck in good condition (1990s house sample).

Figure 55
Example of a wood deck in good condition (1970s house sample; age of deck unknown).

Figure 56 shows an example of a sidewalk in poor condition for a 1970s sample home. Uplift of the sidewalk was caused by growth of a tree planted too close to the sidewalk. In Figure 57, ponding of water on a sidewalk adjacent to a 1990s house sample is apparent immediately following rain. The downspout and splash block discharge to the sidewalk surface.

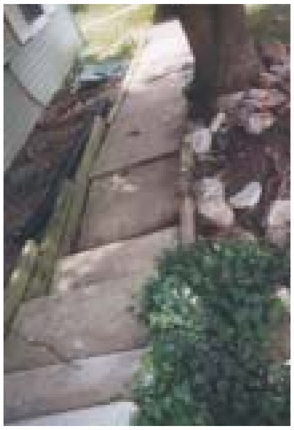


Figure 56
Sidewalk of a 1970s sample house in poor condition due to root movement and growth of a closely located tree.

Figure 57
Ponded water on a sidewalk (1990s house sample).

HOMEOWNER SURVEY

Forty-three homeowner survey forms (see Appendix B) contained answers at the completion of the telephone contacts and site surveys. Twenty-eight respondents provided answers to Question 2, which asked about the maintenance of eight major housing components. Fifteen responses were recorded for Question 3, which asked homeowners/occupants to identify any problems with the home. Seventeen respondents answered Question 4, which asked about natural causes resulting in damage to the home. Only one positive response was recorded for Question 5, which asked respondents about any injuries attributable to the house. Questions 6 and 7 were administrative in nature and related to information needed for the site assessments. Questions 6 and 7 had four and seven responses, respectively.

The following summarizes the meaningful data and findings from the homeowner survey. Statistics are based on a relatively small sample size of only the homeowners who responded. Therefore, the findings should not be considered representative of all homeowners within the study region. The findings, however, do provide some useful insights.

Question 1: Time of Residence

On average, the homeowners in the survey had owned their houses for 13 years (see Question 1 on survey form in Appendix B). The time of residence ranged from one to 29 years.

Question 2: Maintenance

With respondents providing answers for more than one category, a total of 87 answers to Question 2 were recorded.. Table 4 presents a tabulation of the number of responses by the number of components that required maintenance. Table 5 presents the number of responses for each component indicated in Question 2, along with the average number of years since replacement and the average number of years occupants lived in their house. Given that some of the respondents furnished only partial answers (i.e., provided a comment but did not report replacement date), the computation of averages was sometimes based on fewer responses than reflected in the column headed "Number of Respondents."

TABLE 4
RESPONSES TO QUESTION 2

Number of Components Indicated as Requiring Maintenance	Number of Respondents
8	1
7	2
5	3
4	2
3	6
2	10
1	4

TABLE 5
ANALYSIS OF QUESTION 2 RESPONSES

Component	Number of Responses	Average Years Since Replacement	Average Years in House
Roofing	16	6.1	17.6
Paints	16	2.3	11.0
Windows	14	4.4	15.9
Caulking and Sealants	13	1.9	11.1
Siding	11	3.6	15.0
Doors	8	4.0	18.2
Flashing	6	3.8	8.0
Gutters	3	9.3	14.7

The answers to Question 2 indicate that a large proportion of respondents perform maintenance tasks that help prolong the life of a house. For example, 16 of the 28 respondents reported that they had painted, on average within the last 2.3 years (see third column in Table 5). Thirteen reported replacement of caulking and sealants, on average, in the last 1.9 years. Respondents also frequently mentioned major components such as siding, roofing, and windows.

The size of the homeowner survey sample precluded any attempt to draw statistical inferences regarding the two populations of houses. For example, an average frequency of replacement or "return time" can be computed by dividing the number of positive responses for a component by the total house-years in the sample. House-years equals the sum of all responses to the length-of-occupancy question. The house-years for the 43-response sample totaled 504. Dividing 504 into the 16 positive responses for roofing yields a result of 3.2 percent. If this estimate were statistically valid, it would mean that we expect 3.2 percent of the roofs in the sample to be reroofed every year.

Question 3: Durability Problems

Over half of the 15 responses to Question 3 centered on two issues. Five indicated a problem or potential problem related to the foundation or standing water in the basement or crawl space. Another three cited problems related to leaks or water stains around windows. Another two indicated an attic water problem, one related to the fire sprinkler system. The remaining answers varied, citing problems such as nail pops, settling, soffit deterioration, and damage from a fallen tree.

Question 4: Damage from Natural Causes

Seventeen respondents of the 43 answered Question 4, which asked if natural causes had resulted in damage to the home. The question allowed respondents to select from five specific natural cause categories and an "Other" category. Table 6 presents a tabulation of the number of responses to Question 4 by the number of natural causes of damage cited by the respondent.

TABLE 6
RESPONSES TO QUESTION 4

Number of Natural Causes indicated	Number of respondents
1	15
2	2

Table 7 presents the number of responses for each cause indicated in Question 4, along with the average year of the incident and the occupant's average number of years in the house. Given that some of the respondents furnished only partial answers for Question 4, the computation of averages was sometimes based on fewer responses than reflected in the column headed "Number of Responses."

TABLE 7
ANALYSIS OF QUESTION 4 RESPONSES

Cause	Number of responses	Average year of damage	Average years in house
Wind	3	1998	5.5
Hail	3	1997	6.0
Flooding	3	N/A	14.5
Fire	2	1993	18.0
Termites/Bugs	4	1986	23.3
Other	4	1994	8.8

As with Question 2, the small sample size prevents the drawing of statistical inferences regarding issues such as the frequency of the various damage/cause categories. If a larger data set were available, such inferences would be computed in manner analogous to the frequencies for Question 2.

It should be noted that owners/occupants provided little information regarding the extent of damage. None reported catastrophic losses. One respondent indicated $3,000 in wind damage. Another reported minor damage from a fire. Still another reported termite/carpenter ant damage to a deck.

Question 5: Injuries (Fitness of Use)

Only one person responded positively to Question 5, which asked if any injuries were attributable to the house. While 16 respondents indicated damage to the house associated with natural causes, only one injury was reported and it was associated with a flood. The response did not indicate the nature of the injury. No injuries associated with features of the house, such as stairs, were reported.

Discussion

While all of the homeowner survey information must be regarded as anecdotal owing to the relatively small sample size and response rate, larger studies along the same lines are likely to yield more detailed and statistically valid insights into important issues related to housing durability and fitness of use. In particular, the homeowner survey adds time-experience information that complements the "point-in-time" condition assessment results reported earlier.

IV. EVALUATION OF THE METHODOLOGY

During the analysis phase of the project, several improvements to the survey methodology were identified. The first improvement relates to enhancing inspector consistency.

Part of the inspection form required inspectors to check the appropriate block to indicate selected house and site characteristics and conditions. While this approach seems simple and straightforward, the results indicate that some of the inspectors experienced problems. For example, inspectors sometimes disagreed about the number of stories in a house. Difficult-to-classify designs, such as split foyers and walk-out basements, might have contributed to the confusion. Such a problem could be minimized by creating a comprehensive set of detailed, illustrated definitions and a survey guide to better educate inspectors before they attempt any field work. It is also unclear whether certain data, such as house style, are relevant to significant durability concerns. Thus, some assessment data may be eliminated to streamline the assessment process.

The site condition assessment form offered inspectors six choices for the length of overhang: 0", 0-6", 6-12", 12-18", 18-24", >24". Inspectors differed on the size of the overhang for 100 of 208 houses. Approximately one quarter of those responses referenced categories that were not contiguous. While some of the contradictions probably resulted from differences in opinion about the exact size of the overhang, some of the discrepancies may have occurred because inspectors examined different sides of houses with different overhang lengths. Perhaps some inspectors were looking at end gables and others at the sidewalls. This source of error could be removed by modifying the survey form to require data for each side of the house. But this approach raises possible confusion as to what constitutes a "side" of a house for homes with complex plans.

Replacing the multiple-choice approach with one that allows the inspector to write in an estimate might also improve the data. While such an approach would not eliminate disagreements, it would likely offer the analyst better insights into the magnitude of such differences. It may be that the disparity between the resulting point estimates will not be as great as that suggested when the multiple-choice categories are used.

The next section of the site condition assessment survey is the Building Component Condition Visual Survey. In this section, inspectors enter a numerical score to rate the condition of each component. Instructional material furnished to the inspectors provided an explanation of scoring criteria for each component to be inspected. The criteria for some components address not only the condition of a component but also related construction details. For example, the siding assessment criteria corresponding to the "2-Good" category required the siding to be more than six inches above grade and no rot to be present. The "4-Poor" category required siding be less than six inches above the finish grade but permitted rot on up to 15 percent of end joints. The value of a statistical analysis that attempts to relate such scores as these with other data in the survey is questionable. Even if the analyst were able to isolate a statistical relationship, its meaning would not be clear because the score summarizes changes in two different phenomena. If numerical grading is to be used, each category/score should be associated with only one variable.

The numerical scoring section presented another problem. The criteria for scoring used words such as "adequate" and "sound", which call for personal judgment. Accordingly, the scores carry some degree of subjectivity. Since one inspector's "adequate" may not correspond to another's, equal scores may not reflect the same set of conditions; thus, any comparison or averaging of the two scores may be misleading. Because of the complexity of the grading approach, it is entirely possible that inspectors tended to assign ratings based more on personal judgment than on a strict application of multiple criteria.

In view of the above difficulties, a simpler data collection approach focusing on key durability indicators is essential. Such an approach could mean the elimination of numerical scoring in favor of a survey where inspectors place a check in a block or provide an estimate. Such an example was tested on a few homes in this pilot study (see Appendix G). While the results of the test were also plagued by contradictory assessments, the vehicle's straightforward layout seems easier to follow and is less prone to omissions. Features of the streamlined approach could be incorporated into a new form.

Both the site assessment forms and the telephone survey should also include a "none" and "unknown" response for many of the questions so that such situations could be differentiated from each other and from an entry left blank.

V. SUMMARY AND CONCLUSIONS

This pilot study was intended to provide guidance for larger-scale studies of building durability in the at-large housing stock. As such, the study succeeded. In addition, it yielded certain telling findings related to durability in the housing sample:

- Housing Characteristics
  - The size of roof overhangs decreased between the 1970s and 1990s. Eighty-two percent of the 1990s samples had overhangs of 12 inches or less. In the 1970s sample, only 40 percent fell into that range.
  - The use of vinyl window frames increased to 65 percent. Wood and metal frames were the dominant materials in the 1970s.
  - Metal doors became the dominant door type in the 1990s, capturing about two-thirds of the 1990s sample. Seventy-five percent of the doors in the 1970s sample were wood.
  - Vinyl became the dominant siding material. It claimed almost two-thirds of the 1990s sample.

- Housing Condition

    - Site grading appears associated with foundation cracks. Seventy-three percent of houses on lots with surface depressions had visible foundation cracks compared with only 19 percent for those with no identified surface depressions.
    - The occurrence of rot in newer and older homes was 22 percent and 31 percent, respectively. Most rot was associated with wood trim materials.
    - Masonry foundations tended to evidence cracks more frequently than concrete foundations.
    - Most windows and doors were rated in good or adequate condition.

- Homeowner Survey

    - The response rate of the homeowner survey was 21 percent of the 208 houses sampled.
    - The average time of occupancy of respondents was 13 years.
    - Sixteen respondents indicated that they had performed various maintenance activities in recent years.
    - The most common durability problems mentioned by respondents (over half of 15 responses) were related to water, including wet basements and leaky windows.
    - Reports of damage by natural causes covered all causes listed in the survey form; however, the number of responses per cause ranged from two to four. The extent or nature of damage was not generally reported.
    - Only one injury related to a flood was reported; the nature of the injury was not disclosed.

While this study produced important insights into the state of the housing surveyed, it also represented an opportunity to assess different survey methods. The project was intentionally designed to cast a wide net. The assessment form was designed to capture data on a large number of residential features. In addition to the exterior components of the house, it solicited information on features such as driveways, sidewalks, fences, and landscaping. At the same time, it sought some fairly detailed information, such as how the deck material was fastened and whether the patio material was pervious. In addition, the form provided for alternative methods of gathering the needed information.

Based on the results of the data analysis, it appears that the survey would benefit from narrowing the focus of the form to concentrate on the major issues that influence durability, particularly those that were clearly identified in the pilot study. The survey form should also be modified to reflect a single, objective approach that minimizes the exercise of inspector judgment.

VI. RECOMMENDATIONS

Important recommendations from this study include the following:

- The lessons learned from this pilot study need to be incorporated into an improved assessment methodology.

- A comprehensive set of inspector training documents and training materials should be developed for the improved methodology.
- A simplified, user-friendly survey form should be designed and focus on key issues as identified in this pilot study.
- Techniques and procedures aimed at minimizing inspector error should be developed and implemented. They could include creation of a photographic record of each major problem encountered and quality checks of completed survey forms and prompt on-site follow-up to address any discrepancy identified.
- An additional small-scale trial inspection to test the improved methodology should be conducted.
- Once an efficient methodology is finalized, full-scale studies of the U.S. housing stock should be conducted on a regional basis.