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Survey on actual service lives for North American buildings

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Abstract
This paper presents results of a demolition survey in a major North American city that captured building age, building type, structural material and reason for demolition for 227 buildings. The findings challenge many common assumptions about building longevity, and, in particular, the relationship between structural material and service life. Although it is often believed that "durable" structural materials such as steel and concrete will provide the longest service lives for their buildings, our results suggest there is no significant relationship between the structural system and the actual useful life of the building. Reasons for demolition were instead related to changing land values, lack of suitability of the building for current needs, and lack of maintenance of various non-structural components. Only eight buildings identified a specific structural failure. Indeed, the service lives of most buildings are probably far shorter than their theoretical maximum lives; the majority of demolished steel and concrete buildings in our study were less than 50 years old. In the context of sustainable construction, this raises some interesting questions and shifts the spotlight away from durability of materials and on to 1) flexibility of design to allow future changes; 2) deconstructability; and 3) the use of more accurate life span predictions in life cycle assessment calculations on whole buildings.

Introduction

It is generally understood that, within a fairly short time frame, a building will become functionally obsolete, or neighborhood characteristics and land values will change such that the building is no longer delivering the highest value for the land. Nonetheless, many practitioners in the building industry believe that buildings last a long time, and that longevity is related to structural material (1,2), as shown in Figure 1, with wood buildings believed to have the shortest lives. Accordingly, there is an increasing tendency to make assumptions or claims about the relative durability of competing structural materials, particularly for the purpose of highlighting presumed environmental characteristics of those materials.

The assumption that wood can't offer the same durability as steel and concrete excludes it from building applications where longevity is important. In addition, the environmental profile of wood is hurt by this durability image. A short service life has a negative effect on life-cycle environmental analysis results, as the impact of a replacement building will be included in the calculation.

The hypothesis behind this survey was that no relationship exists between structural material and service life of a building, and that buildings are most likely demolished far before the end of the useful life of the structural systems. Building industry beliefs that some structural materials last longer than others are most likely confusing how long a building *could* last with how long it is *actually* kept in service. In fact, a few previous studies indicate that service lives of most buildings are probably far shorter than their theoretical maximum lives. For example, a large study of U.K. residential buildings found 46% of demolished structures fell in the 11-32 year age class (3). Another large study, of office buildings in Japan, found the typical life span to be between 23 and 41 years (4).

While recorded data on age of buildings at demolition is scarce, there are some data on the average age of buildings still standing. Although not as useful as demolition information, which tells us the age at the *end* of the building's life, average ages for existing buildings could be a rough indicator of the average service life midpoint. Sources for this information are organizations with large real estate holdings, such as government agencies or school districts. For example, the U.S. Department of Energy had 10,707 buildings in 2002, with an average age of 31 years (5). Public schools in the U.S. tend to undergo substantial renovations or additions to extend their service lives, thus the average age of the approximately 78,000 public schools in 1998 was 42 years; most schools are abandoned by the age of 60 (6). Other sources of data are agencies responsible for national statistics such as the U.S. Census Bureau. For example, in 2001 the United States had 119,117,000 residential buildings, with an average age of 32 years (7). Statistics Canada reports that the average age of all non-residential buildings in Canada in 2003 was 17.9 years (8).

In this era of increasing interest in sustainable construction, building practitioners are beginning to evaluate environmental impacts of design decisions over the full life cycle of a building. This process, known as life cycle assessment (LCA), requires an estimate of a building's useful life span. More statistical data on actual service lives will assist in keeping LCA results meaningful.

Method

A survey of buildings demolished between 2000 and 2003 in a major North American city was performed (9). The city of Minneapolis/St. Paul was selected for two reasons: it was likely to have a mix of structural materials in its non-residential buildings, and it is located within a state currently undergoing a large building database project with coordination potential in the future.

We obtained city demolition permit records for the period in question, giving us contact information for the building owners. A short written survey was mailed, asking for a few details on each building. This included the age class of the building at demolition (0-25 years, 26-50 years, etc.), the primary structural material of the building (concrete, steel or wood), and reasons for demolition (area redevelopment, too expensive to maintain, etc.). When the building condition was cited as a reason, the survey probed for details.

We collected survey information for a total of 227 buildings, representing 75% of the appropriate demolition records for the period in question. Of these, 105 of the buildings were commercial or institutional and 122 were residential.

Results

About two-thirds of the buildings were wood, a quarter were concrete, and the remainder were steel or various combinations of wood, steel and concrete (Figure 2). The largest concentration of buildings fell into the 76-100 year age group (Figure 3). At this point, it is necessary to separate the analysis into residential and non-residential buildings.

Over half of the sample is houses, which explains the high prevalence of wood. The longevity of houses is likely driven by different factors than those which affect the service lives of non-residential buildings. For example, older homes have characteristics valued by many people, and older homes are often more affordable. In fact a substantial number of standing American homes were built before 1920 – 8.3% in 2001, in other words, almost 10 million units (10). To avoid some of the complex social factors that are unique to housing, we removed the residential buildings from some of the analysis. Wood is still well-represented among the non-residential buildings (Figure 4).

Looking at the age of the non-residential buildings only (Figure 5), there is a clear concentration in the 26-50 year group. In Figure 6, this information is shown segmented by material. Removing the buildings with material combinations, we show the distribution of the 54 non-residential concrete buildings, the 10 non-residential steel buildings and the 30 non-residential wood buildings over the age classes. The results present an interesting contrast with the impressions held by design professionals shown in Figure 1. Only one-third of the concrete buildings lasted more than 50 years, while 63% of the wood buildings were older than 50 at demolition, and the largest group of those fell in the 76-100 year age class. Meanwhile, 80% of the steel buildings fell below the 50-year mark, and half of those were no more than 25 years old.

Comparing age with structural material helps illustrate possible correlations, but we also directly investigated whether or not the structural system was the primary motivation for the demolition. Looking once again at the entire data set of 227 buildings, Figure 7 shows the distribution of respondents' reasons for demolition, which they selected from a list. About 38% (70 respondents) selected "building's physical condition" as the main reason. Those respondents were then asked to elaborate. The vast majority (54 of them) selected "lack of maintenance," presumably with respect to various non-structural elements. Only eight selected "specific problem with structural or other material or system" (3.5% of all buildings). Of those, seven mentioned foundation problems and one mentioned wood decay. Six of these buildings were older than 75 years, one was in the 51-75 year group, and one was of unknown age.

Figure 8 segments the distribution over the top four demolition reasons by structural material. Surprisingly, given that they are the youngest in the data set, most of the steel buildings were demolished because they were no longer suitable for their intended use or due to their physical condition. For the wood buildings, physical condition was the dominant reason. This almost certainly is due to an age effect, since "physical condition" as the main reason for demolition predictably correlates with age of the building (Figure 9), and the wood buildings are the oldest in the data set.

Discussion

While wood is believed to have a short life expectancy due to risk of fire or biodegradation, the wood buildings in our study had the longest life spans. The majority of demolished wood buildings were older than 75 years, while over half of all the demolished concrete buildings fell into the 26-50 year category. These data indicate that wood structural systems are fully capable of meeting longevity expectations. In addition, wood might well be a preferred material in a design scenario that recognizes actual service lives are short – in those cases, materials that enable easy building modification for changing needs and materials that are easy to recover when the building is decommissioned would be favored.

Although the wood buildings in our sample lasted the longest, our overriding conclusion is that no meaningful relationship exists between structural material and average service life, and that most buildings are demolished for reasons that have nothing to do with the physical state of the structural systems.

The vast majority of buildings in this sample fell into just three categories of reasons for demolition: area redevelopment (34%), lack of maintenance (24%), and building no longer suitable for intended use (22%). The most common reason, redevelopment, is completely unconnected to the physical components of the building; this is a change to the use of the land, for example, converting an industrial site to housing.

For buildings identified as no longer suitable, most were likely too small and were to be replaced with a larger version of the same type of building, as is often the case with houses. Some of the buildings in this category may have been considered unsuitable due to technical obsolescence of some components or systems, and an upgrade was deemed too costly. However, in none of these buildings was a specific failure of a component identified.

The buildings which were demolished due to lack of maintenance (24%) are of interest for further study. While the structural system was presumably still functional in all of these, failures in the other components led to a shortened service life for the entire building. Our study did not probe for details about those failures.

In sustainable design, "durability" is increasingly being included on priority lists under the assumption that designing for longevity is an environmental imperative. However, this is unsupported in the absence of life cycle assessment and accurate lifespan predictions. In the worst case, designing for longevity can lead to design choices that are well-intentioned but, in fact, yield poor environmental results. For example, a building component with low embodied environmental effects, such as wood cladding, can be replaced many times before totaling the high embodied effects of a material such as brick. If the brick cladding ends up in landfill after 40 years of use, it was a poor choice on an environmental basis. The best environmental scenario for that brick is recovery at year 40, for re-use in another project. Rather than attempt to predict the future and design permanent structures with an infinite lifespan, we are probably better off in acknowledging our inability to make such predictions and instead design for easy adaptation and material recovery.

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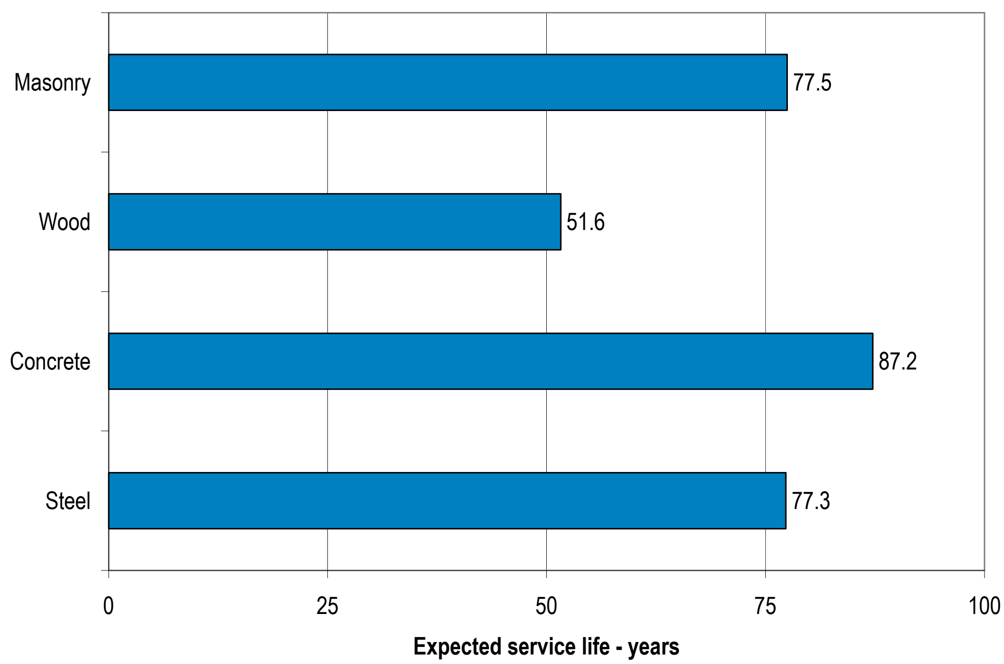

Figure 1 **Average expected service life for non-residential buildings by primary structural material.** From surveys of architects, structural engineers, builders and developers in the United States and Canada (1,2). N=683.

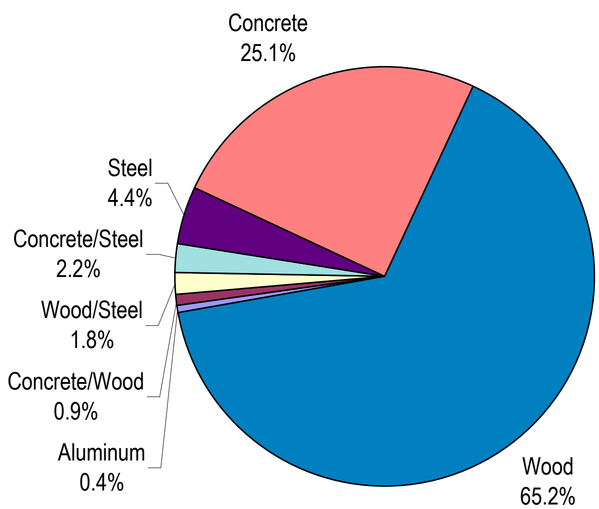

Figure 2 **Proportion of all 227 demolished buildings by primary structural material.**

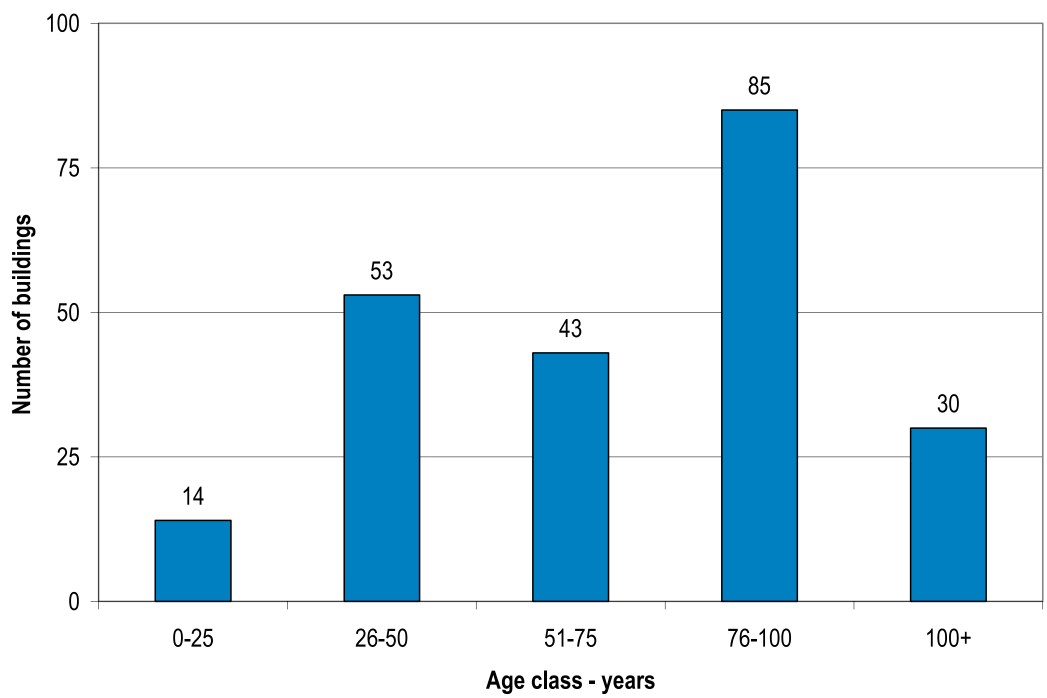

Figure 3 **Distribution of all 227 buildings by age class.**

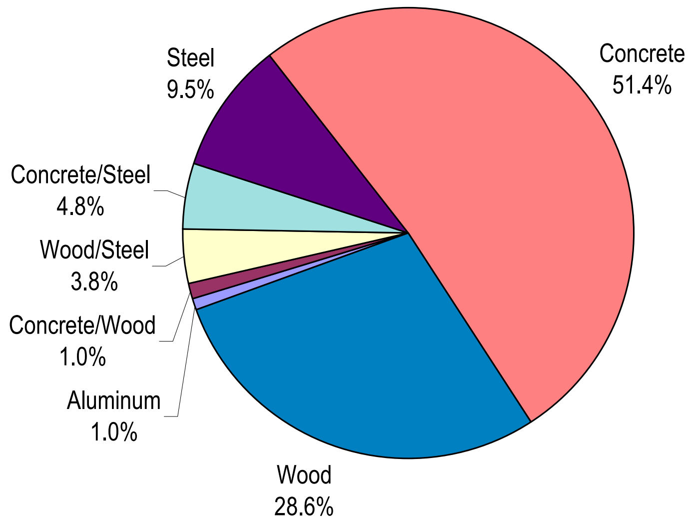

Figure 4 **Proportion of the 105 non-residential buildings by primary structural material.**

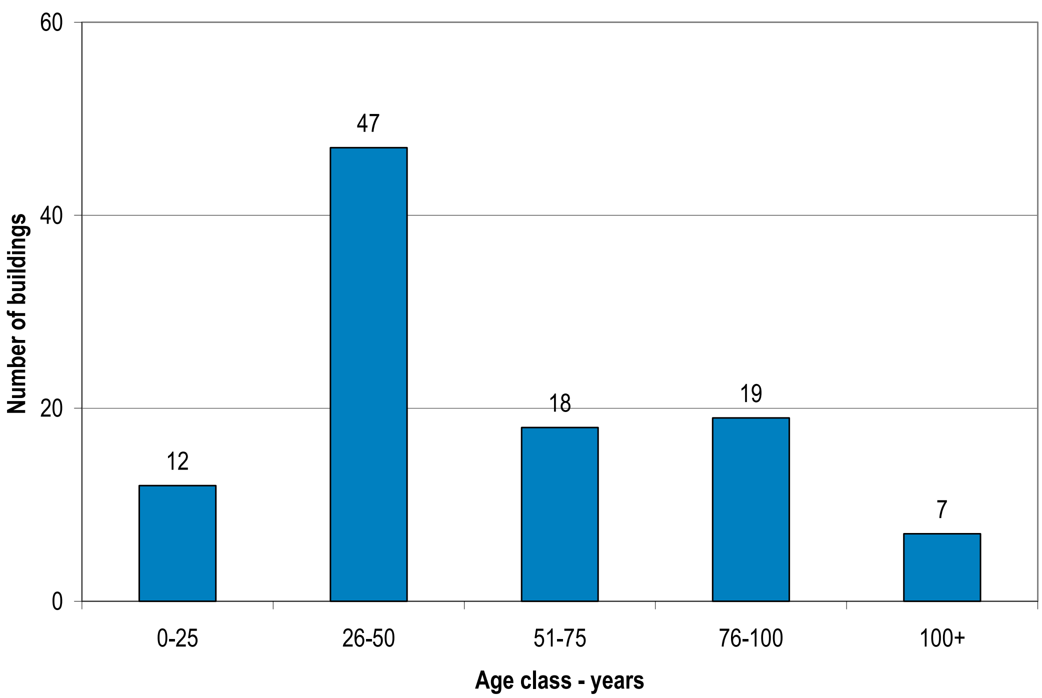

Figure 5 **Distribution of the 105 non-residential buildings by age class.**

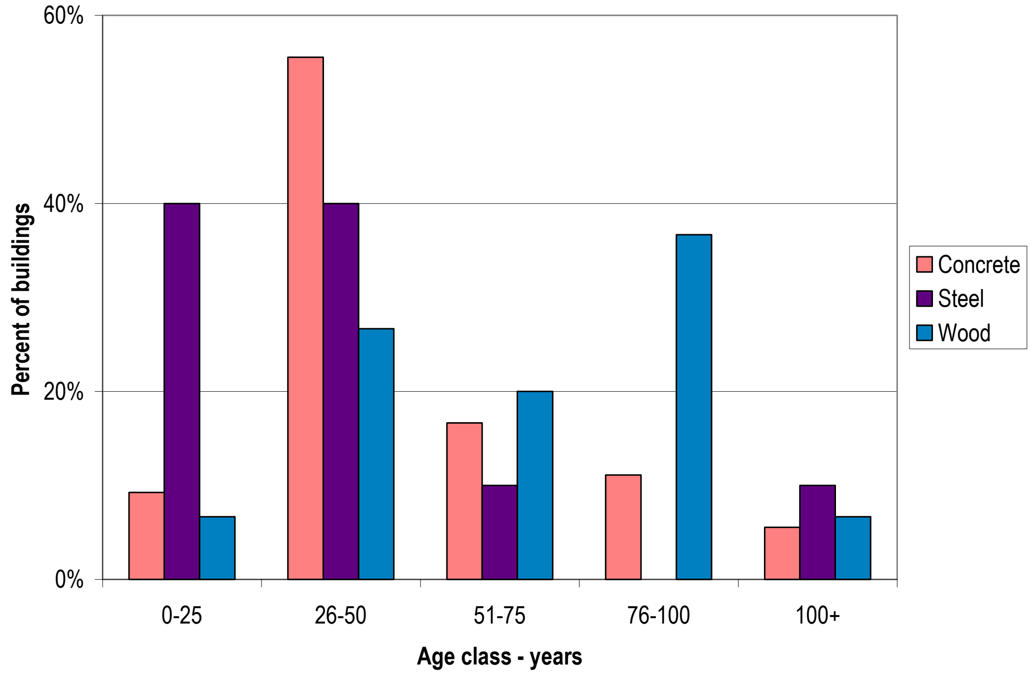

Figure 6 **Distribution of 94 non-residential buildings by age class and by structural material** (buildings with combinations of materials excluded).

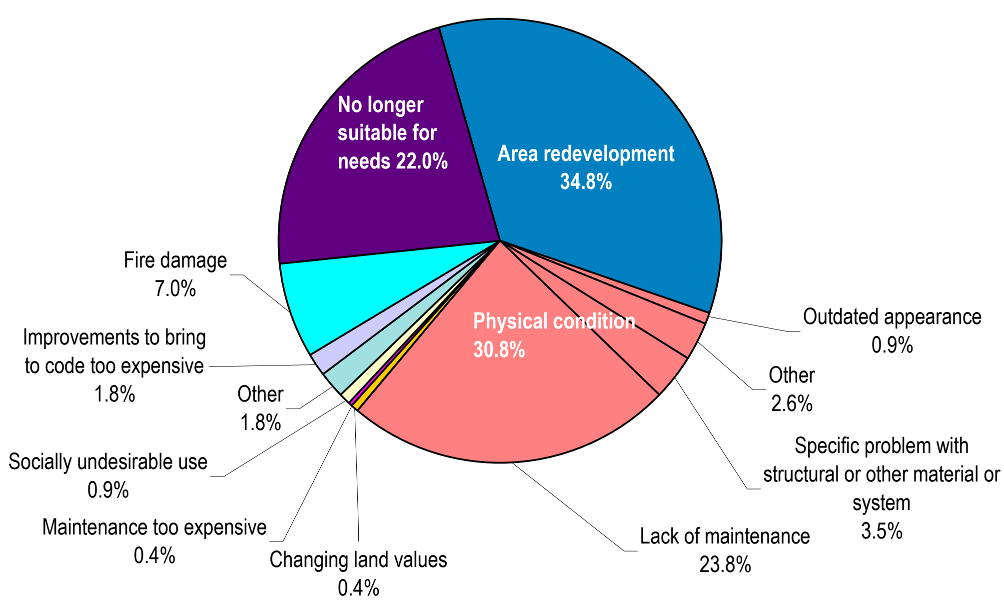

Figure 7 **Distribution of "reason for demolition" responses for all 227 buildings.**

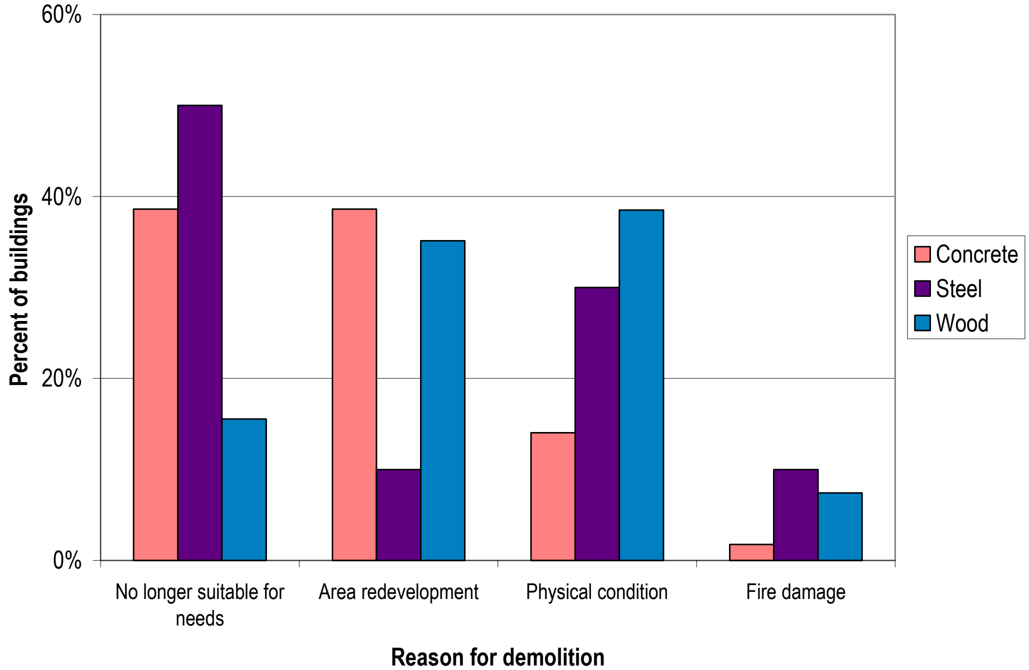

Figure 8 **Distribution of buildings by material, over the top four reasons for demolition.** N=206. Combination buildings excluded.

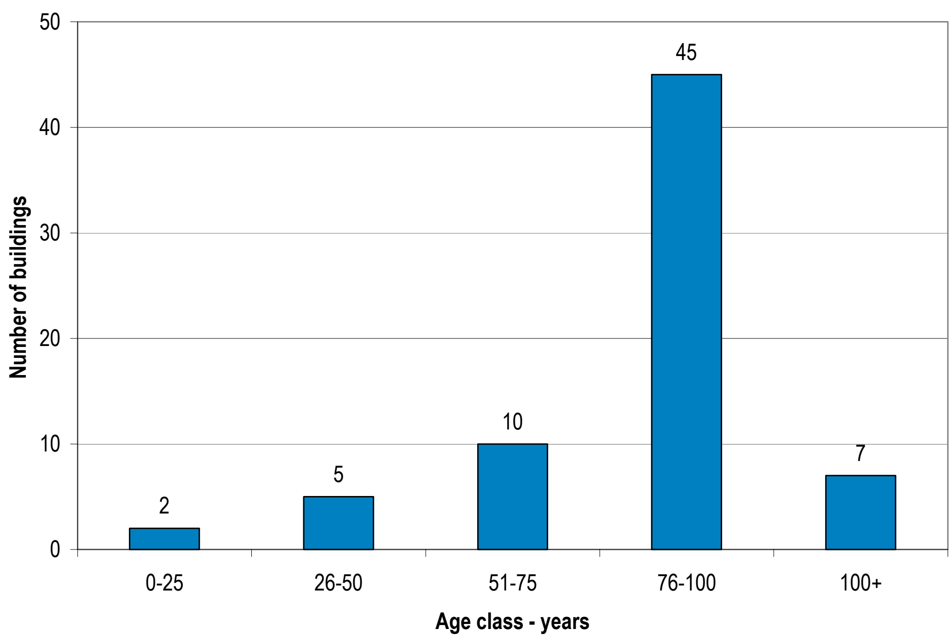

Figure 9 **Distribution of buildings stating "physical condition" as the reason for demolition, by age class.** N=69.