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Common Bond

A newsletter on maintenance and preservation for owners of architecturally significant religious buildings

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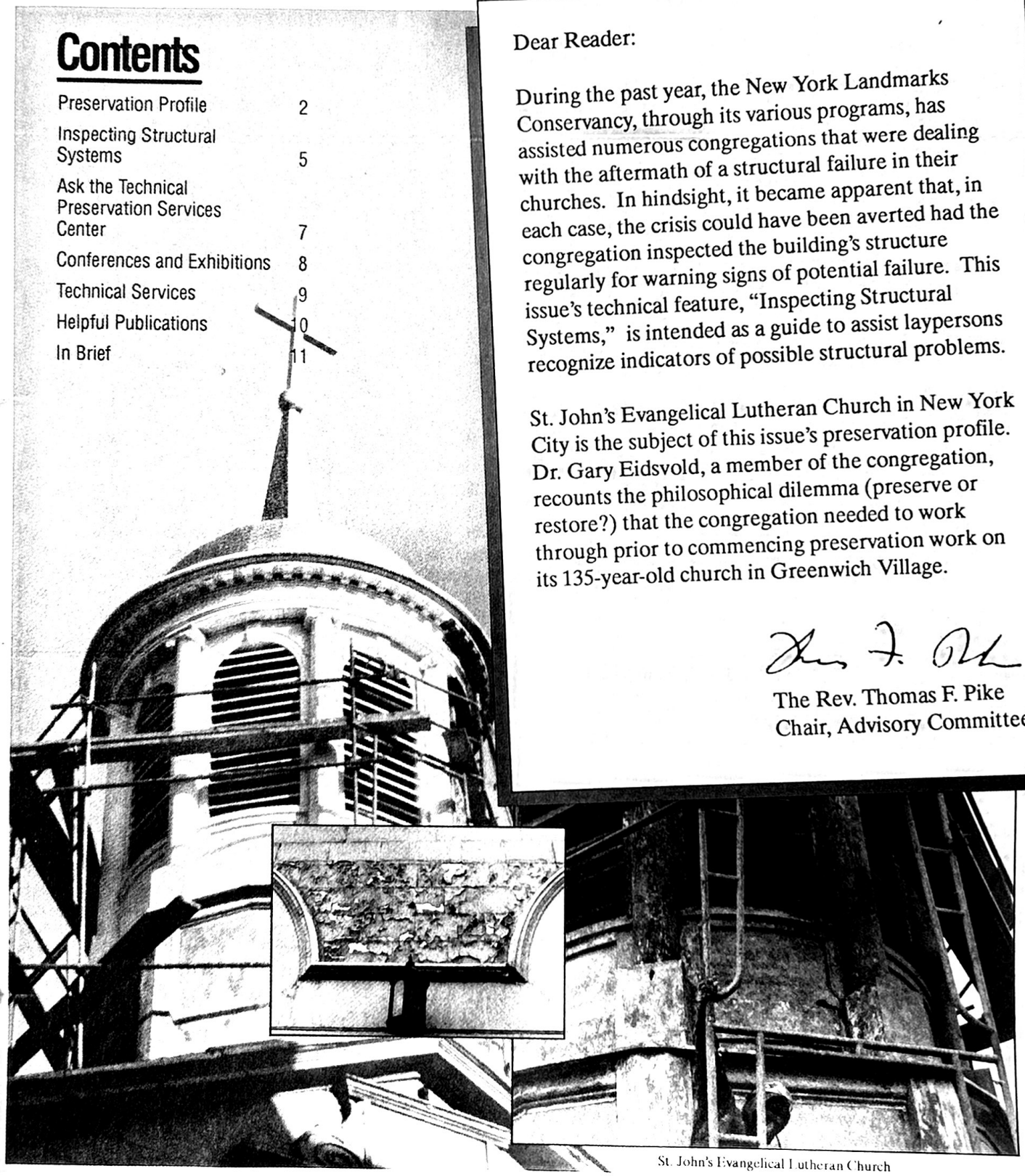
Dear Reader:

During the past year, the New York Landmarks Conservancy, through its various programs, has assisted numerous congregations that were dealing with the aftermath of a structural failure in their churches. In hindsight, it became apparent that, in each case, the crisis could have been averted had the congregation inspected the building's structure regularly for warning signs of potential failure. This issue's technical feature, "Inspecting Structural Systems," is intended as a guide to assist laypersons recognize indicators of possible structural problems.

St. John's Evangelical Lutheran Church in New York City is the subject of this issue's preservation profile. Dr. Gary Eidsvold, a member of the congregation, recounts the philosophical dilemma (preserve or restore?) that the congregation needed to work through prior to commencing preservation work on its 135-year-old church in Greenwich Village.

The Rev. Thomas F. Pike
Chair, Advisory Committee



St. John's Evangelical Lutheran Church

Inspecting Structural Systems

The structural condition of any building is an essential aspect of its overall integrity. Older churches and synagogues that have survived for many years are generally assumed to have proved themselves structurally. However, there is no absolute measure of structural adequacy for older buildings. Structural conditions change as buildings age, and deterioration may reduce the effectiveness of a building's structural components. Consequently, it is important that older buildings be regularly inspected for signs of structural damage or failure so that corrective measures can be taken before the condition escalates to a larger and more expensive problem.

A comprehensive structural evaluation of a building can only be performed by a qualified structural engineer. Nevertheless, a layperson can learn some of the basic principles of structural behavior and be trained to identify potential problems. The purpose of this article is to explain certain basic structural concepts and to point out some of the key indicators of structural failure that the layperson can recognize.

BASIC PRINCIPLES OF STRUCTURAL BEHAVIOR

Inspecting a building's structural system need not be a mysterious undertaking. A basic understanding of the various members (engineers call each component of a building's structure a "member") that make up a structural system as well as some knowledge of the role that each member plays can make this a less daunting task—and one that is beneficial for the building and the people that use it.

The structure of a building is designed to carry the weight of the building materials as well as that of people, furniture and so forth. In addition, a successfully designed structural system enables these various "loads" (see below) to be transferred from roofs and floors to columns or to bearing walls and ultimately to the foundation, all through logical and identifiable paths. Most structural systems have a level of redundancy that prevents a building from collapsing should one member fail. Roofs and floors, of course, have other structural functions. They brace walls and columns, and they provide lateral stability to the building. Consulting a qualified structural engineer should help clarify the load/structural system of your church, synagogue or meeting house.

LOADS: In order for a building to be considered safe, its structure must be adequate for the load demands placed on it (Figure 1). "Load" refers to the strain placed on a building's structural components by gravity, vibration or use. These forces generally fall into four categories. The dead load consists of the weight of the building materials themselves and other immovable elements in the building, such as pipe organs, pulpits and fixed altars. The dead load can be changed over time through additions and alterations. The live load is made up of the changing, non-permanent weight that acts on a building, such as people, movable furnishings and snow on the roof. The wind load refers to the force that wind has on a building. Dynamic load

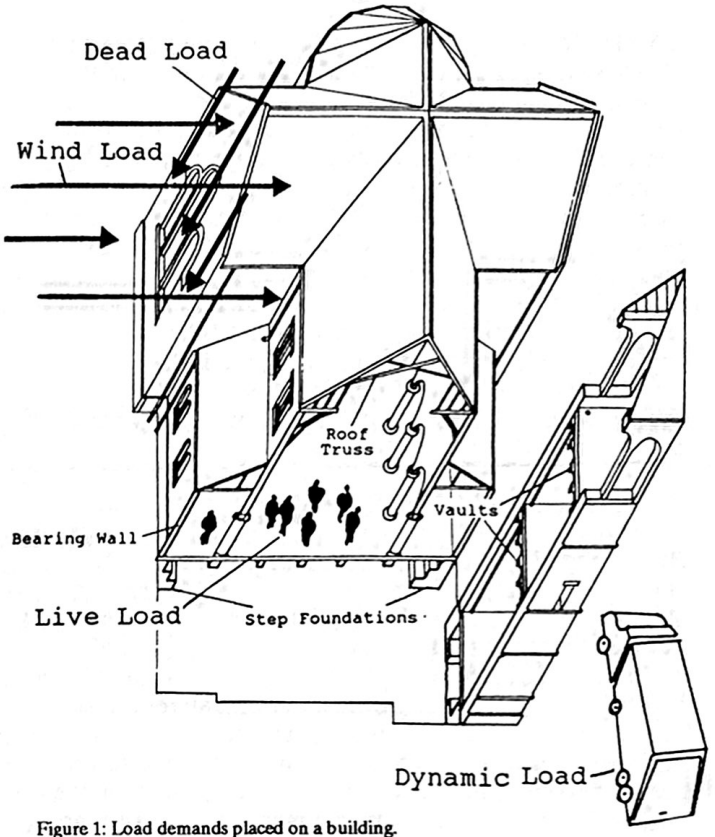


Figure 1: Load demands placed on a building.
Drawing: Wes Haynes

describes the effect of vibration and ground movement on a building, such as that caused by traffic, adjacent construction and earthquakes, or by building-induced forces caused by bell ringing or the vibrations from mechanical equipment.

STRESSES: Loads can cause several different types of stresses on a building's structural components (Figure 2). Tension is caused by two forces pulling apart. Compression results from two forces pushing together. Shear results from parallel forces acting in opposite directions. Torsion results from forces acting in a twisting motion. Most of the time, all of these stresses act on the various structural components of a building in combination.

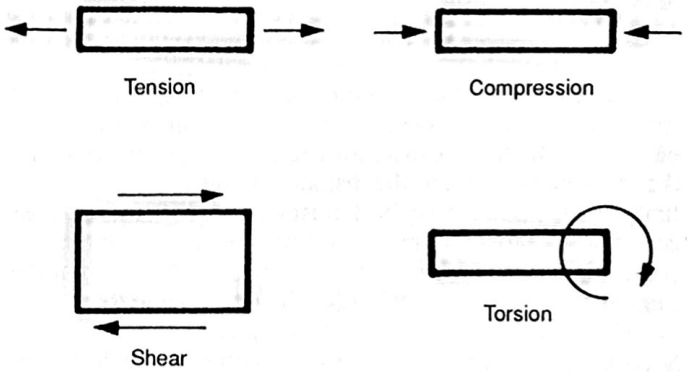


Figure 2: Stresses that act on building materials.
Drawing: Tom Ryan

ENVIRONMENTAL FACTORS: Environmental factors also have a significant impact on a building's structural system. Building materials expand or contract in response to daily and seasonal changes in temperature and the moisture content of the surrounding environment. Every material has a different rate of expansion and contraction. For example, steel will expand at twice the rate as brick as the temperature rises. Because large portions of a building are exposed to the outside environment, the various structural components of any building will be in constant motion in response to exterior and interior temperature fluctuations. The rates of expansion and contraction vary from material to material and can cause cracks. These cracks can allow water, which can cause extensive deterioration, to penetrate the structural components of a building.

RECOGNIZING POTENTIAL PROBLEMS

ROOF TRUSSES: It is not uncommon for the roof trusses of an older building to develop structural problems. Composed of a framework of straight or curved structural members, roof trusses form the primary component of a roof's structure (Figure 3). While they can be arranged in a variety of triangular configurations, almost all roof trusses have a top chord (in compression), a bottom chord (in tension) and web members which connect the chords (in tension or compression depending on their position in the truss). The critical components of most timber trusses are the bottom chord and the connections to the other truss members.

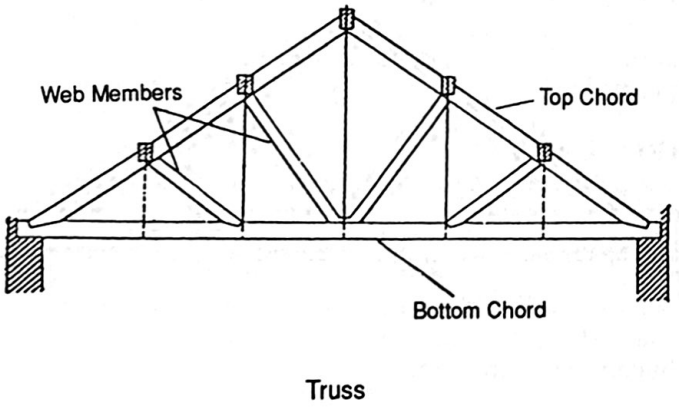


Figure 3: Cross section of a roof truss.
Drawing: Tom Ryan

The stresses placed on the connections where different structural members of wooden roof trusses meet are particularly high. The distance from the side of the timber to the connecting bolt and the distance from the end of the timber to the connecting bolt must be adequate for a proper connection. Most failures in roof trusses occur at bolted connections that were either inadequately engineered at the time of construction or that have since failed due to deterioration. When examining roof trusses, look for horizontal and vertical deflection (bending in one direction or another), loose or separated connections, splits in the wood members (particularly at connections), bowed members, moisture deterioration and insect damage.

WALLS: Load-bearing walls play a critical role in the structural stability of a building. Besides carrying the load of a wall's own dead weight, load-bearing walls also carry loads from the roof and floor structures. They must also be able to absorb the forces created by people and moving objects within the building and external forces produced by the wind and vibration.

Load-bearing walls are usually braced by the floor and roof systems and by connections with other load-bearing walls within the building. However, unlike most residential and commercial buildings, religious buildings often do not have intermediate floors which provide this bracing function because of the need to create vast interior spaces. For this reason, the walls of many religious buildings, particularly masonry ones constructed in one of the various Gothic styles, are stiffened by buttresses. Buttresses also serve to prevent the roof trusses and interior ceiling structure from pushing the walls out. Religious buildings which do not have buttresses were often constructed with extraordinarily thick walls in order to resist these structural forces.

Masonry walls frequently lean or bow. The outward leaning of exterior walls at the eaves is common because of the considerable thrust exerted against the walls by the roof trusses. Masonry walls will often lean because the foundation has moved over time, because of a deficiency in the anchoring system of the floor or roof, because the wall is not thick enough for its height and surface area or because excessive loads are placed on the wall. They also lean because the brick or stone masonry units are inadequately interconnected or because water penetration has caused the mortar to disintegrate. If the wall of a building is out of plumb more than 1/3rd of its thickness in overall height, or 1/6th of its thickness in one story, an engineer should be called in immediately to investigate the problem (Figure 4).

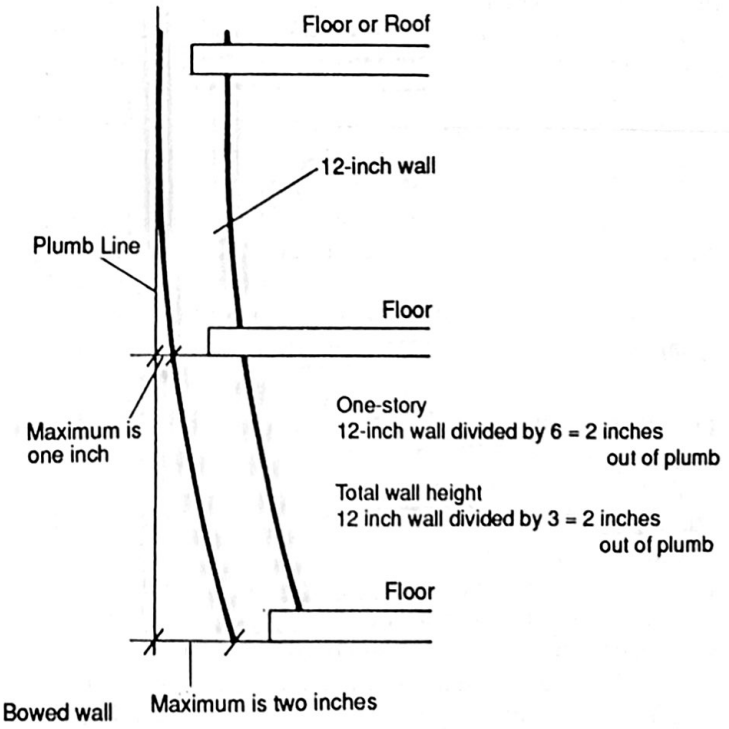


Figure 4: Walls out of plumb more than 1/6 of their thickness in one story or 1/3 of their thickness in overall height should be investigated by an engineer.
Drawing: Tom Ryan

Many building owners find cracks in their walls particularly worrisome. Cracks can be caused by several factors acting separately or in combination. For instance, the expansion and contraction of building materials due to changes in temperature or moisture can cause cracks. Cracks may also be a sign of much more serious structural problems. Determining the cause and effect of cracks requires the expertise of a structural engineer.

ARCHES: An arch is a curved structural member which spans an opening or recess. Arches are composed of an assembly of masonry units, usually brick or stone that are interlocked to support themselves and the building structure above. Arches vary in shape from the horizontal flat arch through the semicircular to acutely pointed arches. When inspecting arches, check for crushed masonry, cracks or leaning arch supports. Call an engineer to assess the safety and stability of the arches if there is any question regarding their structural stability.

FLOORS: Floors can be constructed with various materials including wood, reinforced concrete, structural steel and masonry. Floors are supported either by bearing walls or beams and columns; they also provide lateral bracing for walls. All floors are subject to some vibration, but in structurally-sound floors this "springiness" should be barely perceptible. When checking floor structures, look for sagging, excessive vibration, moisture deterioration, insect damage (typically from below the floor), inadequate connections to supporting members and cracks or splits in the supporting structure. Also check for damage that may have been caused by alterations. Often the floor structures of older buildings have been compromised because of modifications made to the plumbing, gas, electrical or heating systems.

CONCLUSION

The structural system of a building should be inspected every three years. Check timber trusses annually. Keep a record of your inspections, taking care to describe any signs of distress, such as the width of a crack, where it occurred, etc. Try to determine if the problem is local or widespread. Consult a structural engineer whenever new cracks develop in trusses or in masonry walls, or when large (greater than 1/8" wide) cracks develop in masonry. An engineer should inspect the building when excessive deflection or sagging are noted in roof or floor, when walls or columns are leaning, when serious deterioration due to water or insect damage is evident or when renovations affecting the structure of the building are proposed. A structural engineer will review these conditions and the effect they have on the building structure, and recommend proper corrective measures.

This feature is based on article prepared by Mr. Thomas Ryan of Ryan-Biggs Associates of Troy, New York, for the Conservancy's Technical Preservation Services Center.

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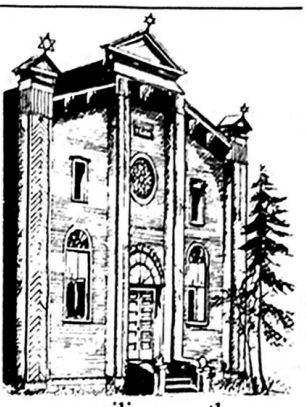
Ask the Technical Preservation Services Center

Question:



Our roof will be replaced this spring but previous leaks left white and brown stains on the original wood ceiling paneling of our synagogue. What must be done for the stains, please?

Janet Chapman
Beth Joseph Synagogue,
Tupper Lake, New York

Answer:

Both the white and brown stains on your ceiling are the result of water damage. White stains are generally superficial and only affect the surface of the wood and its protective finish. The brown stains are somewhat more serious as they indicate that moisture has penetrated deeply into the wood itself. Both are common problems associated with natural wood finishes such as shellac, varnish, wax or oil. Many home remedies are available to improve the appearance of stain-damaged wood finishes. You will have taken the most important step by eliminating the source of the water damage.

Three popular methods of removing water stains are touching up, bleaching and sanding. Touching up involves a combination of cleaning and spot painting or repainting. Special "touch-up" paint colors for this purpose are available in paint and hardware stores. Bleaching entails applying a common household chlorine bleach to the affected areas. Sanding consists of scouring the surface with an abrasive embedded in paper or cloth. Rarely is only one method sufficient when restoring wood finishes. A combination of each may be required for complex staining conditions. In order to determine which of the three methods work best, it is a good idea to test each method first. Test patches should be confined to the most inconspicuous areas where they won't be seen. Compare the results carefully.

A number of factors will influence the choice of the best treatment for restoring natural wood finishes. These include the type and location of the wood as well as the amount of wear it receives. At Beth Joseph Synagogue, the wood used for the interior paneling appears to be a fir or a reddish softwood (Figure 1). The muted grain of softwoods is usually easier to match when refinishing than that of the sharp and vividly grained hardwoods. Because the synagogue's ceiling paneling receives no wear, the durability of its finish is not a significant concern. However, its location is an important consideration in choosing the appropriate method of repair.

White stains can almost always be removed by touching up. Touch-up paint colors can usually be improved when mixed with an appropriate thinner (water for a water-based paint or a little solvent, such as turpentine, for an acrylic paint). If large areas are stain-damaged, a thinned alkyd semi-gloss paint that matches the woodwork can be used. However, because this treatment will be obvious if used over