CHAPTER 7
STRUCTURAL SYSTEMS

Senior housing and care facilities have used virtually every structural system normally employed in relatively simple structures: wood frame, masonry bearing wall and concrete plank, structural metal stud, steel, precast concrete, poured-in-place concrete, and so on. The selection of the appropriate system or combination of systems is usually the result of an evaluation of at least 12 factors.

Conditions in selection of structural systems

1. Soil conditions
2. The program and concept
3. Applicable codes
4. Potential code changes
5. Flexibility
6. Impact on finished-ceiling and building height
7. Material delivery and construction timing
8. Local construction capabilities and preferences
9. Ease of construction and schedule
10. Cost of the selected system
11. Cost impact on other systems
12. Appearance and aesthetic potential

CONSIDERATIONS

This chapter reviews these 12 factors and how they can lead to the choice of a system. This section is followed by a review of typical issues faced when using the most common structural systems.

Soil Conditions

Poor soil conditions can have a major impact. A site requiring expensive piles may choose a system such as steel that has longer spans and requires fewer footings and supporting piles. Unstable or variable soils, subject to differential settlement, may preclude less flexible systems, such as bearing walls. In addition, the presence of a high water table may preclude the inclusion of a basement, especially for buildings over four stories. If poor soil found on a site dictates that it must be removed prior to construction, the inclusion of a basement may be more economical because soil must be removed anyway. Some soil types, when located in zones subject to seismic activity, can dictate much of the structure. As these examples indicate, it is advisable to have some basic geotechnical data prior to making the selection of a structural system or the decision to include a basement.

The Program and Concept

The program of uses and whether they will be directly above or below one another from floor to floor is also a major factor. A building that contains only nursing units or apartments can select from the simplest systems because the required spans are short. Spaces such as major dining or multipurpose rooms need longer spans and are likely to be reconfigured over time, and mid- or high-rise stacking of program is likely to require more complex systems.

Applicable Codes

At least three code issues directly impact the choice of a system: the required loads and subsurface soil conditions, the building code use group and related permitted construction type, and special structural requirements to deal with extraordinary conditions such as a hurricane or earthquake. In addition, the choice of floor systems can be influenced by fire-rating requirements, the ability to run mechanical systems and sprinkler lines, and the assembly thickness when overall building height is an issue. The typical design live loads are 40 pounds per sq ft (psf) for residential units and 100 psf for common spaces.

If unusually heavy loading is required in some areas to account for special radiology equipment, compact files, rooftop mechanical equipment, or swimming pools located above grade within the building structure, the added dead load for these items for that part of the structure can be in the range of 100 psf for mechanical systems to up to 300 psf for some compact file systems. If known in advance, these loads can be supported by most systems.

More prescriptive are the use groups and construction types incorporated in most codes. Some states define assisted living, the housing parts of a CCRC, congregate living, and other senior living options as multifamily housing. In many states, housing can be wood-frame up to four stories. In others, wood-frame senior housing is permitted but restricted to one or two stories.

In addition, a growing number of state and local codes mandate structures that can withstand extreme stresses or loads, such as those generated by hurricanes or earthquakes. In most cases, these requirements point the design team toward the more complex and often more costly systems, such as steel or concrete in multistory construction.

Potential Code Changes

The codes governing senior housing and care facilities are all subject to change, and some of these changes can influence the selection of a structural system. For example, the International Building Code, which many states are now adopting—in whole or with modifications—as their state building codes, has the potential to alter the system choice. In this code, assisted living facilities with more than 16 units are defined as use group I-1, and combustible structural frames, such as wood, are permitted for structures up to four stories high.

In general, there has been a trend toward more code restrictions on the use of combustible structures for frail or confused populations that are hard to evacuate. Some experts argue that the addition of sprinklers as well as smoke and fire protection is far more important than the relative combustibility of the structure, but this argument is not necessarily prevailing.

In general, it is good practice to design to meet any likely future code requirements. This avoids the need for future waivers or upgrades in other systems (such as sprinklers).

Flexibility

Most successful buildings have to accommodate some growth and change. Over the last 20–30 years, senior living environments have had to accommodate more change than many other building types. For example, the increased frailty of many occupants, the desire for more space and privacy, and other factors have required many sponsors to reconfigure the basic building blocks of their facilities: resident rooms, nursing units, or apartment units. Some structural systems, such as the use of bearing walls between units (vs. exterior walls and one corridor wall) can be very inflexible. The altering of concrete planks may also be problematic if the desire is to cut through the floor, as structural strands generally cannot be cut. Wood-frame and larger span structures tend to be more accommodating of change.

Impact on Finished-Ceiling and Building Height

Some structural systems, such as two-way (flat-plate) concrete slabs or bearing walls and concrete plank, allow the design team to minimize floor-to-floor height. The structure is only 7–9 in. thick and can double as the finished ceiling. Other systems, such as trusses or structural steel beams, are often 10–15 in. deeper, and usually need to be covered by a hung ceiling that adds 14–18 in. more than flat-plate or concrete plank floors to the overall floor-to-floor height.

Material Delivery and Construction Timing

The choice of a system can have a significant impact on the project schedule. Some structural materials, such as wood, concrete blocks, poured-in-place concrete, and structural studs, are readily available. Others, such as structural steel, can have long lead times. Careful planning can reduce the schedule impact, but delivery time can still influence the choice of systems.

Local Construction Industry Preferences and Capabilities

Virtually all local construction markets have preferred systems, as well as systems that are rarely used. For some areas, prestressed or post-tensioned concrete, for example, is rarely used. Local preferences and familiarity typically result in lower costs.

Ease of Construction and Schedule

In addition to local preferences, some systems are selected due to their ease of construction (particularly wood or metal-stud framed buildings) and the construction schedule, to diminish the impact of severe winter weather conditions. If the construction schedule is such that concrete would be placed or masonry bearing walls constructed during winter months, the steel-frame or structural-stud building system is often selected to avoid the necessity of heating and protecting the structure while concrete or mortar cures.

Cost of the Selected System

Because of the economics of most senior living projects, first cost is always a major factor.

Cost Impact on Other Systems

What has been less well understood by many owners and their design teams is the structural system's cost impact on other building systems. For example:

- The systems that add to floor-to-floor height can add significantly to the costs of interior partitions, exterior skin, and other systems.
- When systems must be covered, at least part of the cost of the dropped ceiling and soffits should be considered in the structural cost
- Some systems, such as wood roof trusses in some states, require additional sprinklers and fire protection.
- Some systems, such as bearing walls and structural steel, can complicate (and increase the cost of) the distribution of ducts, conduits, and other systems.

▸ *Trusses at the Weinberg Village Winter Garden are both structurally functional and aesthetically important. Weinberg Village, Pittsburgh, Pennsylvania. Perkins Eastman Architects PC. Photograph by Jim Schafer.*

CHARACTERISTICS OF STRUCTURAL SYSTEMS

	Spans appropriate for resident units	Spans appropriate for large spaces	Flexibility	First cost	Impact on other system costs	Appearance	Material delivery and construction timing	Impact on interior space and building height	Responds to current and future codes	Familiar to local construction industry	Impacted by soil conditions
Wood Frame	○	⊘	○	○	○	○	○	○	⊘	○	○
Structural stud	○	⊘	○	○	○	○	○	○	○	⊘	○
Bearing wall and concrete plank	○	X	X	○	⊘	⊘	⊘	○	○	○	⊘
Steel and concrete plank	○	○	○	⊘	⊘	⊘	⊘	X	○	○	○
Steel and poured concrete deck	○	○	○	⊘	⊘	○	⊘	X	○	○	○
Precast concrete	○	○	⊘	⊘	⊘	○	⊘	⊘	○	⊘	○
"Beam & Slab" poured in place concrete	○	○	○	⊘	○	⊘	○	○	○	○	○
"Flat plate" poured in place concrete	○	⊘	⊘	⊘	○	○	○	○	○	○	○
Prestressed/post-tensioned concrete	○	○	⊘	X	○	○	○	○	○	X	○

○ Not often a significant issue
⊘ May be a problem or issue
X Often a significant problem or issue

Source: Perkins Eastman Architects PC.

Appearance and Aesthetics

It is uncommon for the structure to be expressed in most senior living environments, but when it is, its appearance can be important. For example, some design teams dislike the joints inherent in the plank system. Others find the running electrical services and sprinkler lines on the ceilings created by flat plate concrete slabs to be a significant aesthetic problem, and therefore place these utilities in walls. There are, however, some opportunities to expose the structural system as an important part of the project's design vocabulary.

STRUCTURAL SYSTEM TYPES

Based on the factors discussed above, there are some issues that come up frequently in the review of options. The following is a brief summary of the discussion surrounding nine of the most common structural systems.

Wood-Frame

With the exception of buildings in some urban areas, senior housing is predominantly wood-frame. This system is typically inexpensive, it can be implemented by a wide variety of contractors, it is fast, and it can be flexible. The span limitations can be overcome with trusses, laminated beams, heavy timber, or mixing with steel or other systems in larger spaces. The most common reason for not using wood is current or probable future code restrictions on combustible structural systems.

Another potential disadvantage is that the flooring surface can feel bouncy underfoot in high traffic areas.

Structural Stud

The use of steel studs instead of wood is common. It often has a slightly higher material cost, but it is noncombustible. Its other advantages and limitations are similar to those of wood-frame construction, yet an additional problem can occur especially in exterior walls. Water damage or moisture problems can lead to a loss of structural integrity, even if the steel is galvanized.

Bearing Wall and Concrete Plank

A third frequently used option is a combination of masonry bearing walls and precast concrete plank. Again it is a simple method, familiar to many contractors, relatively low in cost, and relatively quick to implement. The span limitations can be overcome by mixing it with other systems for larger spaces. The major problems with this system are its relative lack of flexibility; performance on unstable soil; height limitations (50–70 ft in most construction markets); impact on the distribution of mechanical, electrical, plumbing, and fire-protection systems; and the occasional shortages of masons and/or precast companies. Senior housing projects often have large quantities of open dining and common space on ground-level floors, which become difficult to achieve with this system. In addition, many design teams object to using the underside of the planks as the ceiling for the space below. When this objection leads to having a hung acoustical tile or sheetrock ceiling to cover mechanical/electrical distribution systems and the uneven joints between planks, some of the cost advantages of this system are eroded.

Steel and Concrete Plank

The fourth option eliminates some, but not all, of the objections to bearing wall and plank. This option has minimal height limitations (as long as the beams are in the same plane as the walls), is quite flexible, performs adequately on unstable soil, and rarely suffers from a lack of skilled manpower. On the other hand, steel requires fire-proofing, hung ceilings are almost always required, steel can have long delivery times, and the floor-to-floor heights are greater.

Steel and Poured-Concrete Deck

This option has somewhat the same characteristics as the steel and plank system, except that it is more costly and the depth of the system is greater than that for steel and concrete plank, due to the inclusion of intermediate beams.

Precast Concrete

Precast concrete can be used for more than exterior wall systems. It is also used in some locations for the columns, beams, and bearing walls. It is also a common structural choice for garages, site bridges, and other simple long-span, heavy-load structures. Some areas, however, are not served by a nearby sophisticated precast company. Moreover, many senior living facilities do not have the scale and degree of repetitiveness necessary for precast to be cost effective.

"Beam-and-Slab" Poured-in-Place Concrete

Concrete is commonly used in many parts of the country. It is a particularly common choice for projects that must have a noncombustible structure or must withstand significant lateral loads, such as those produced by hurricanes. It is also relatively easy to build in most local construction markets, and it can produce a relatively flexible building. Poured-in-place, however, tends to be relatively expensive and often has greater thickness than steel-and-concrete plank.

"Flat-Slab" Poured-in-Place Concrete

A two-way, flat-slab concrete structure is a common choice for taller residential buildings since it minimizes floor-to-floor height, is fast to build, creates a finished ceiling with the underside of the slab, permits flexible column placement, and is relatively easy to brace or stiffen for lateral loads. This option, however, requires substantial reuse of forms (usually created by a mid- to high-rise program) and an experienced structural concrete subcontractor to make the cost acceptable. Even when these conditions are met, flat-plate structures are usually substantially more expensive than some of the other options.

Prestressed and Post-Tensioned Concrete

These two options have some of the same advantages and disadvantages of flat-plate, but are less frequently used. The systems can be thinner than flat-plate but are also more costly. In addition, there is less flexibility in cutting the concrete in future modifications, due to the locations of structural steel tendons embedded in the concrete. The construction industry in many parts of the country does not have the experience to implement these systems.

As a final point, it is common to employ two or more systems in a single project. In some CCRCs, for example, poured-in-place has been used for the foundations, precast in the garages, structural stud for residential wings, and structural steel for the common areas. Overall, the selection and design of a structural system, or combination of systems, is an issue with significant cost, aesthetic, and functional implications.