A Balanced Design Approach to Firesafety for Low-rise Multifamily Construction

Fire Prevention Through Education

A balanced design approach to firesafety for low-rise multifamily buildings should include fire prevention education, along with 2-hour noncombustible compartmentation of dwelling units, supplemented by automatic smoke detection and suppression systems.

INTRODUCTION

Deaths, injuries, and property losses due to fire in the United States have remained unacceptably high over the last several years. This dilemma is well known throughout the fire protection community, but is just beginning to attract the attention of the media and public awareness groups. Unfortunately, most of the media attention has focussed primarily on life-safety concerns. The other side of the story, namely, fire's destructive impact on property, has generally been overlooked.

Decisions on fire-related issues in the code-making process are now largely influenced by life-safety concerns. In some cases, reductions in fire resistance of building elements are granted with the installation of 13R sprinkler systems, even though these systems are designed essentially for life-safety purposes. This creates a protection imbalance that decreases the amount of property protection afforded, and eliminates a level of redundancy that is important to a building's overall fire protection scheme.

The time has come to initiate a change in the fire protection design of buildings that will insure future improvement in the country's fire record. Balanced design, incorporating both active and passive protection, is the solution.
PURPOSE

The purpose of this report is to: (1) describe the concept of a balanced design approach to firesafety, (2) explain why it is needed, (3) emphasize the urgency of its implementation; and, (4) illustrate the cost benefits of concrete and masonry construction used in a balanced design approach to firesafety of low-rise multifamily housing.

THE BALANCED DESIGN CONCEPT

In its most basic form, balanced design represents a philosophy that utilizes the combined strengths of property-protection and life-safety components in a systems approach to firesafety. When applied to building design, this translates into fire resistive compartmentation supplemented by automatic detection, alarm, and suppression systems. In addition to the physical components, a case can be made for inclusion of a strong fire prevention education program as a component, since this is an intrinsic part of any good comprehensive fire protection plan. A further description of these components is provided in the paragraphs that follow.

COMPONENTS OF BALANCED DESIGN

1. Prevention and Education - Although fire prevention is not a tangible element in a fire protection scheme, its inclusion through education is of paramount importance. Obviously, if all fires could be prevented, there would be no need for traditional fire protection systems. Since this is unlikely to ever occur, fire protection features must be called upon to perform when prevention has failed. In essence, the three components described below are back-up systems to the fire prevention process.

2. Compartmentation - Considerations involving compartmentation and structural fire resistance should be made early in the planning stage of a building's design. Compartmentation of dwelling units in multifamily buildings limits the extent of fire damage to property, reduces the probability of a multiple-fatality fire, and provides a higher level of safety to firefighters. A building's inherent fire resistance (passive protection) is the first and foremost design consideration in any fire protection package. If all else fails, it remains in place as the last line of defense against fire. Since code provisions requiring one-hour fire-resistance rated dwelling-unit separations have had no apparent success in improving the fire record, it is recommended that dwelling-unit separations be constructed of two-hour noncombustible assemblies. This report will later show that concrete and masonry are especially well-suited for this application in low-rise multifamily buildings due to economic reasons and other considerations.

3. Automatic Detection and Alarm - For multifamily dwellings, early warning systems typically consist of a network of smoke detectors. These systems are mainly provided for life-safety purposes, but they also create an opportunity for earlier notification of the fire department. Proper installation of automatic detection and alarm devices, combined with regular maintenance and testing, are crucial to this system's effectiveness.

4. Automatic Suppression - The most common type of suppression system found in buildings is an automatic sprinkler system. For multifamily occupancies, this should be a system designed and installed in accordance with National Fire Protection Association (NFPA) Standard 13(2) or 13R(3).

Newly constructed low-rise multifamily buildings (four stories or less) are likely to be equipped with the 13R system. Its function is to aid in the detection and control of fires, thereby increasing the chances that building occupants will be able to evacuate the premises. The 13R system is essentially life-safety oriented, affording a lesser degree of property protection due to the omission of sprinklers in certain areas.

Conversely, the NFPA 13 system is a full coverage system, with its origin emanating from property protection concerns. It is designed with more emphasis on control and extinguishment of fires than the 13R system.

Because of the distinct differences between the two types of systems, construction modifications (tradeoffs) that have been used with NFPA 13 (full coverage system) installations, are not justified when 13R (partial coverage) systems are provided.

WHY BALANCED DESIGN IS NEEDED

Figs. 1a and 1b show the plight of the U.S. fire experience involving apartments over the last several years. In general, code changes and legislative attempts have had very little success in reducing fire losses. The one exception occurred during the late 1970's and early 1980's, when a surge in smoke detector use contributed to a substantial reduction in residential fire deaths.

In subsequent years, however, the decline in fire fatalities has leveled off, suggesting that the maximum life-saving potential of smoke detectors has been reached. One explanation is that the current use level of smoke detectors has become too extensive for any increased usage to be statistically significant. Another
possibility could be a reduction in system performance due to operational failures of detection devices. Tests conducted on smoke detectors after just 10 years of service indicate failure rates ranging from 16.1% to as high as 29.6%.

Sprinkler systems also have shortcomings. They are ineffective against fires of exterior origin, and are dependent upon an adequate water supply that may be unreliable at times. Closed or damaged sprinkler control valves, broken water mains, and high consumption resulting in low water pressure are common causes of such lack of reliability. Like any mechanical system, sprinklers require a good maintenance program to be effective.

Utilizing noncombustible construction and compartmentation as the sole element of protection is not the total answer either. If doors are left open in a fire, or penetration openings are not properly sealed and protected, the effectiveness of a barrier is substantially reduced.

Each of the protection components has individual strengths, but only by combining these elements into a balanced design will any significant improvement in the U.S. fire record be realized.

THE URGENCY OF IMPLEMENTING BALANCED DESIGN

With the exception of the almost immediate impact that early smoke detector use has had in reducing fire deaths in the late 1970's and early 1980's, progress on improving this country's poor fire record has been traditionally slow. Evaluating the success or failure of newly implemented fire protection requirements also takes time.

Fig. 2 reveals that 85% of residential fire fatalities occur in buildings that are 20 years of age or older. This suggests that a minimum evaluation period of twenty years is needed in order to adequately assess the impact that building construction practices and fire protection systems may have on the fire record.

Building codes will continue to struggle on fire safety issues during the next several years, but the fire problem involving multifamily dwellings is likely to be resolved only after a balanced design concept of fire protection is adopted by codemakers. There is a sense of urgency about this, because twenty years must pass before a meaningful evaluation can be made as to the influence of today's construction practices and fire protection systems on the fire record. With balanced design, there is no time lost experimenting with systems of lesser protection in hopes that they will be able to do the job. Balanced design is already at the highest end of the protection spectrum. Its implementation may be the only
way of assuring that this country's fire experience will steadily improve in the years ahead.

ECONOMIC BENEFITS OF CONCRETE AND MASONRY IN A BALANCED DESIGN APPROACH

Cost will be a major consideration in the widespread acceptance of balanced design. Since its benefits will be measured over the next couple of decades, construction materials will have to withstand the test of time. It follows then that the economical aspect should be assessed with long-term considerations in mind rather than conducting an analysis based on first costs.

A 1988 report submitted to the U.S. House of Representatives' Committee on Science, Space and Technology at their hearing on Firesafety in Multifamily Housing indicates that low-rise multifamily buildings constructed of concrete and masonry will result in substantial savings over a 30-year evaluation period, compared to similar buildings of wood-frame construction.

The following example is abstracted from the above referenced report, omitting detailed calculations for brevity. Final results have been calculated using established life-cycle costing techniques and formulas.  

### EXAMPLE

**Given** - Two 3-story buildings of identical size and shape. Each contains ten, 1008 square foot dwelling units per floor, totalling 30 units. Each unit consists of 2 bedrooms, a kitchen, a living room, and a bathroom (see Fig. 3). Floor-to-ceiling height is 8 feet. One building utilizes wood-frame construction for the floors, walls, and the roof truss assembly. One-hour fire-rated separations are provided between all dwelling units. The second building is of noncombustible construction utilizing concrete or masonry walls and concrete floors and roof. Two-hour fire-resistance rated separations are provided between all dwelling units. Both buildings have brick-faced exterior walls, and are provided with NFPA 13R sprinkler systems and hard-wired smoke detectors.

![Fig. 3. Floor plan for two-bedroom apartment unit.](image)

**Elements Analyzed and Compared** -
- Initial Costs
- Mortgage Costs
- Property Taxes
- Insurance Costs
- Rental Income
- Equity Build-up

**BASIS OF ANALYSIS:**

**Life-Cycle Cost Parameters** -
- Number of periods (years) analyzed = 30
- Nominal discount rate (including inflation) = 7.4%
- Inflation = 4.4% (based on 35-year average)
- Cost of borrowing money = 3.0%
Initial Costs -

Initial costs consist of a cash investment equal to 20% of the building value, plus loan origination fees (points) of 3% of the mortgage. Costs associated with exterior face-brick, smoke detection systems, and 13R sprinkler installations are ignored because they are equal for both buildings, thus creating no cost differential.

Building values of the two structures are calculated as $1,325,419 for concrete and masonry and $1,228,651 for wood-frame, reflecting an initial cost difference of $3.20 per sq ft more for the concrete and masonry building. The inclusion of loan points increases this difference by $0.08 per sq ft.

Mortgage Costs -

For both buildings: 10% fixed-rate mortgage amortized over 25 years, no balloon payments, and an 80% loan-to-value mortgage.

Property Taxes -

Property taxes are assessed and adjusted every 4 years based on a tax multiplier of .06 times the actual cash value of the building (replacement value less physical depreciation). Taxes are assumed to remain fixed between assessment periods, and the tax multiplier is constant for the duration of the 30-year analytical period. Building appreciation and depreciation rates used in determining the tax basis are described in the "Equity-Build-up" section that follows.

Insurance Costs -

Insurance rates are 10-year averages of the combined "building", "contents", and "extended coverage" rates in Illinois, but are not unlike those found in other parts of the country (rate differential multiplier of 5.5 to 6, based on construction type). For wood-frame construction, the rate is $.453 per $100 of building value. For concrete and masonry, it is $.083 per one hundred dollars.

Premiums increase 5% each year including inflation over the 30-year analytical period, 4.3% due to the average escalation of actual cash values of buildings over the last 30 years, and 0.7% due to the annual average escalation of insurance premiums over a 10-year cycle.

Additional rate development parameters include 80% coinsurance; $1000 deductible; "loss of rent" rate based on a factor of 62% of the average combined rate; insurance coverage limits are 100% values for "building" and "loss of rents" coverage; and, limits applicable to the owner's contents are ignored. Since sprinklers are provided in both buildings, their influence on insurance rates, if any, has no differential effect in the cost analysis.

Rental Income -

Initial gross income for each building is established using a break-even analysis, whereby the building owner has a zero net income after operating expenses and debt service (mortgage payments) are paid. This translates into monthly rents of approximately $651 per unit for the concrete and masonry building and $626 per unit for the wood-frame building. Rental incomes increase at the rate of inflation over the remaining building life.

Operating expenses are assumed identical for both buildings, and therefore do not influence the comparative results of the life-cycle cost analysis.

Equity Build-up -

Replacement-cost building values reflect an average rate of escalation of 5% annually (rounded from 5.2%) based on results over a 30-year period.

The amount of physical depreciation of the wood-frame building is determined from tabular values based on a 45-year life expectancy. Tabular values for the concrete and masonry building correspond to a life expectancy of 55 years.

Fig. 4 shows the results of the life-cycle cost analysis. Positive values indicate a per-unit savings with the concrete and masonry structure. Negative values indicate per-unit comparative losses.

The net savings of $8,075 per unit (a building total of $242,250) represents the amount of money in 1988 dollars that can be saved during the 30-year building life by constructing a low-rise multifamily building with concrete and masonry, rather than wood-frame construction.

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Fig. 4. Present-worth savings for concrete and masonry low-rise multifamily construction compared to wood-frame over a 30-year building life.
The example illustrates that over the long run, concrete and masonry construction is a less expensive construction alternative for low-rise multifamily housing than wood-frame. As an additional benefit, concrete and masonry construction used in conjunction with balanced design should increase the effectiveness of a 13R sprinkler system. Since there are no unsprinklered combustible concealed spaces present, the 13R sprinkler system meets the more stringent requirements of an NFPA 13 system. In effect, concrete and masonry construction improves the design coverage of the 13R system, making it more efficient.

CONCLUSIONS

1. Attempts to improve the U.S. firesafety record to date have had limited success in reducing deaths, injuries, and property damage.

2. A balanced design approach to firesafety combining the strengths of active and passive protection elements is the solution to improving the nation's poor fire record. Concrete and masonry construction used within the framework of balanced design is especially well-suited to address the fire problem in multifamily housing.

3. Utilizing concrete and masonry building systems for construction of low-rise multifamily housing makes the balanced design concept more efficient and economical than if it is used in conjunction with wood-frame construction.

4. For low-rise multifamily construction, the recommended components of a balanced design are: (1) the presence of a fire prevention educational program, (2) two-hour rated concrete and masonry compartmentation, (3) automatic detection and alarm systems, and (4) an NFPA 13R automatic sprinkler system.

5. There is a sense of urgency in having balanced design adopted by codemakers. Since 85% of residential fire fatalities occur in buildings that are twenty years of age or older, twenty years must pass before a meaningful evaluation can be made assessing the impact that today's construction practices and protection systems will have on the U.S. fire record. Further delays in implementing balanced design, in favor of lesser fire protection schemes, is not prudent.

REFERENCES


Organizations represented on the CONCRETE AND MASONRY INDUSTRY FIRESAFETY COMMITTEE

| BIA | Brick Institute of America |
| NCMA | National Concrete Masonry Association |
| PCA | Portland Cement Association |
| ESCSI | Expanded Shale, Clay and Slate Institute |
| NRMCA | National Ready Mixed Concrete Association |
| PCI | Precast/Prestressed Concrete Institute |

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