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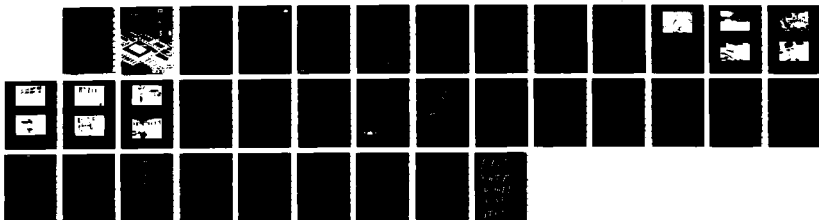
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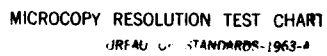
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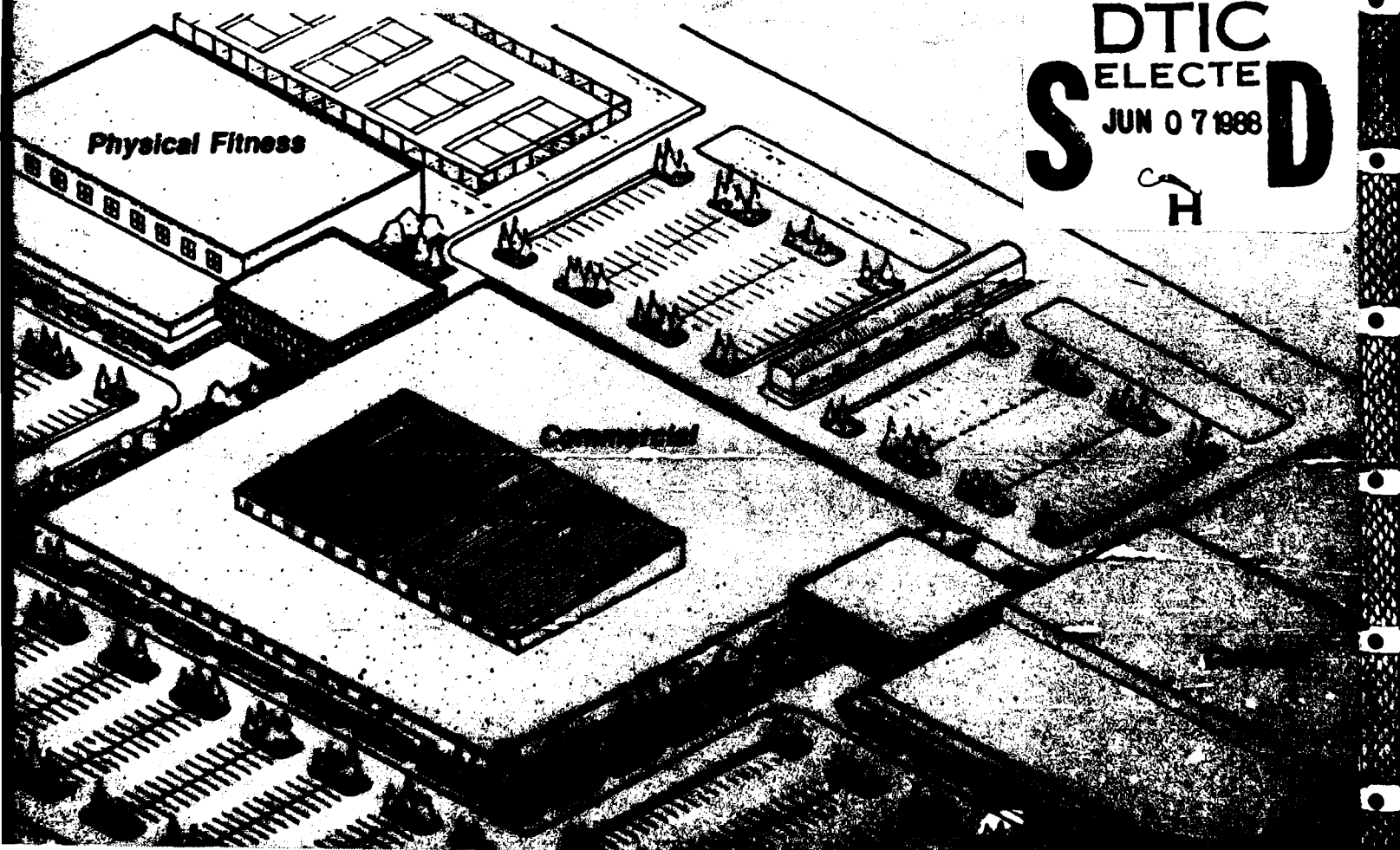
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### *Composite buildings for military bases*



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*Cover: Axonometric view of the proposed shopping mall-community center for Fort Wainwright, Alaska (after Livingston-Slone 1987).*

# CRREL Report 88-4

March 1988



## *Composite buildings for military bases*

Stephen N. Flanders

Prepared for  
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## PREFACE

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Portions of the report are based on contractor studies of composite buildings as an alternative to conventional building concepts. The contractors were: Livingston-Slone, Inc., for the shopping mall-community center; USKH, Inc., for the mobilization buildings in Alaska, and Campbell Design Group for the mobilization buildings at Fort Leonard Wood, Missouri.

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**CONVERSION FACTORS: U.S. CUSTOMARY TO METRIC (SI)  
UNITS OF MEASUREMENT**

These conversion factors include all the significant digits given in the conversion tables in the ASTM *Metric Practice Guide* (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

| <i>Multiply</i>           | <i>By</i>                    | <i>To obtain</i>   |
|---------------------------|------------------------------|--------------------|
| inch                      | 25.4                         | millimeter         |
| foot <sup>2</sup>         | 0.09290304                   | meter <sup>2</sup> |
| British thermal unit      | 1055.056                     | Joule              |
| Btu/hr ft <sup>2</sup> °F | 5.678263                     | W/m <sup>2</sup> K |
| degrees Fahrenheit        | $t_{°C} = (t_{°F} - 32)/1.8$ | degrees Celsius    |

# Composite Buildings for Military Bases

STEPHEN N. FLANDERS

## INTRODUCTION

Composite buildings—single structures that house a variety of functions traditionally found in several buildings—have gained thorough acceptance at remote military sites in Alaska. This paper reports on the results of four studies of composite buildings. Two studies compare using composite buildings to accommodate mobilization in Alaska and at Fort Leonard Wood, Missouri. The third study is of an operational Canadian Forces composite building. And the fourth examines a community center-shopping mall for Fort Wainwright, Alaska.

The studies compare composite buildings with conventional military construction based on:

1. Construction costs.
2. Life-cycle costs.
3. Speed of construction.
4. Materials availability.
5. Energy efficiency.
6. Fire safety.
7. Organizational efficiency.
8. Incremental or modular construction.
9. Habitability.

The study of the Canadian Forces composite building showed that it uses only 53% of the energy of institutional buildings in an equivalent climate. The study of composite buildings as an alternative to M-design\* frame buildings for mobilization showed that nonresidential composite buildings were cheaper to build and to operate in Alaska. Fire safety requires that composite buildings be of more permanent construction than M-design buildings. The study for Fort Leonard Wood indicated that the higher quality construction of composite buildings would be more expen-

sive than M-designs. In all cases composite buildings save energy.

The studies suggest that *composite buildings should be considered as alternatives to conventional buildings for base expansion.*

## A CANADIAN MEGASTRUCTURE

The Canadians have successfully employed composite buildings for military bases. The Canadian Forces base at St. Jean, Quebec, is an example. This 1.3-million-ft<sup>2</sup> building houses basic and advanced training facilities. Figure 1 depicts the current building during the 1977-78 construction period, among the wooden buildings that it replaced. The megastructure constitutes 77.3% of the base's building area.

The average overall base energy consumption, normalized to square feet and degree days\* has been 17.5 Btu/ft<sup>2</sup> °F-day, including gas heating and electricity. This compares with 33.2 Btu/ft<sup>2</sup> °F-day for large institutional buildings in the similar climate of Michigan (Boonyatikarn 1983). The megastructure uses an outdated dual-duct HVAC system. Air is initially cooled by a chiller working at a fixed capacity and ducted to the space. A parallel duct carries heated air that is mixed with the chilled air to provide the desired temperature in the space. This can be likened to driving a car with the accelerator pedal floored and the brake used to

\* Energy consumption has been normalized to compare different-sized buildings in different climates. Normalization is as follows:

$$NBE = \frac{(ABE)}{(SF)(HDD + CDD)}$$

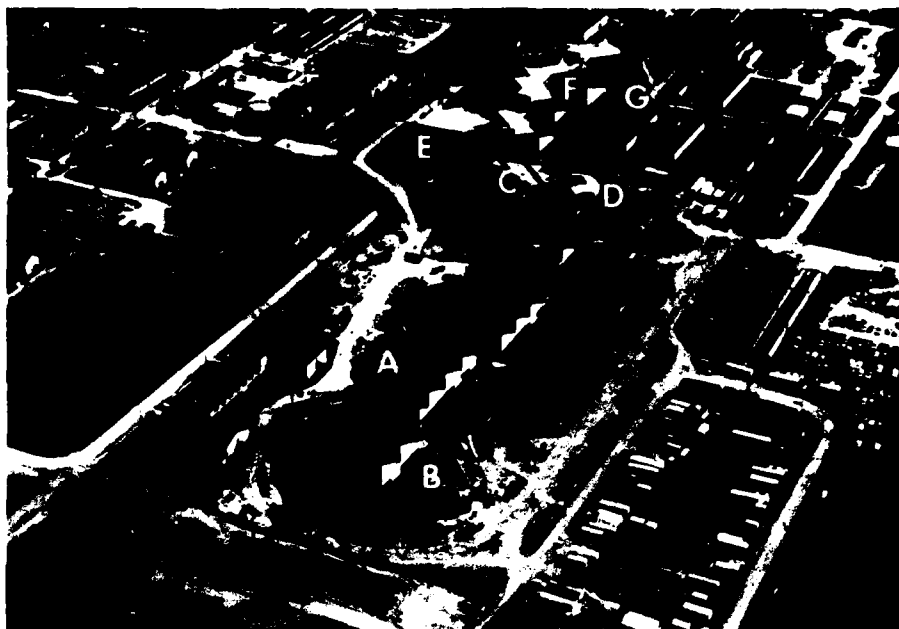
where ABE = annual building energy consumption (Btu)

SF = building floor area (ft<sup>2</sup>)

HDD = heating degree-days (°F-day)

CDD = cooling degree-days (°F-day).

\* M-design buildings are standard designs of diverse buildings that will be needed during mobilization. Typically, the construction is wood framing and plywood.



*Figure 1. Aerial view of the Canadian Forces Base at St. Jean, Quebec, under construction during the winter of 1977-78 (courtesy of Canadian Forces, St. Jean, Quebec). A—transient quarters for 1600; B—classroom, administrative and service complex on the first two levels; C—VIP transient quarters; D—main entrance atrium; E—athletic facilities; F—barracks for 780 recruits; G—dental clinic.*

control speed. Energy was cheaper when the building was built; the designers chose dual-duct HVAC for its precise temperature control. Air-conditioning is primarily to offset internal sources of heat.

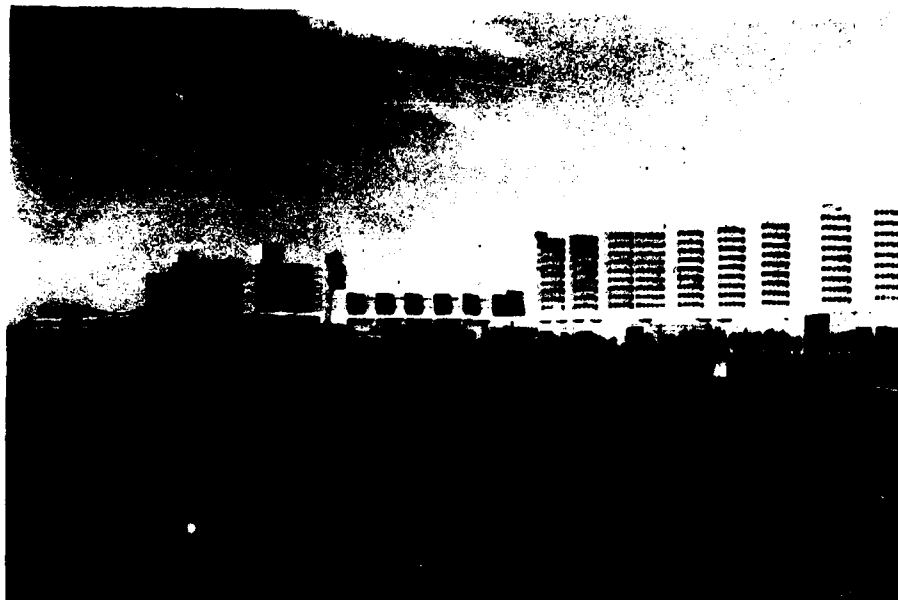
Users of the megastructure find the building to be efficient and essentially trouble-free. Troops muster and march between classes in the broad corridors. There are ample exterior views from barracks, mess halls and other public areas. The compact layout of the building minimizes requirements for vehicle travel on the base.

The building looks complicated (Fig. 1). In fact, each element is easy to comprehend. The building is oriented north-south (north is the lower left-hand corner in Fig. 1). The building comprises a two-story pedestal containing classrooms, administrative, athletic, health, dining and other service facilities. The third floor (visible as a white layer above the pedestal) contains the mechanical systems. The upper multi-story levels are residential. The north series of nine-story adjoined towers ("A" in Fig. 1) contain residences for 1600 tran-

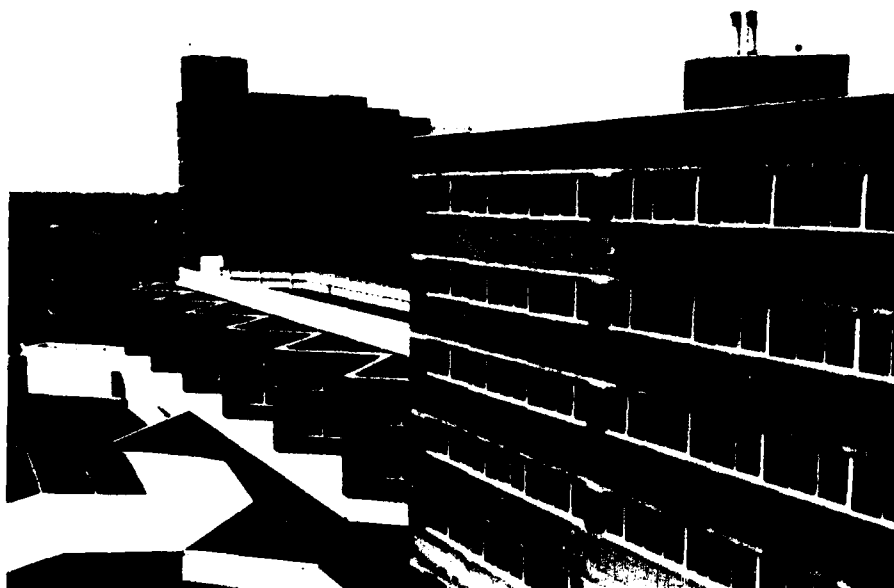
sient people engaged in curricula of typically 75 to 90 days (some language courses are from 3 to 10 weeks). The south tower complex houses 780 recruits on seven floors.

Figure 2 shows some exterior views of the megastructure. Figure 3 shows a typical classroom and library that support the training functions of the building. Although the building is large, public areas (Fig. 4) have access to natural light and outdoor views. The residential areas (Fig. 5) have ample window areas. *The utility system is conveniently accessible within the mechanical space* of the third floor (Fig. 6). Figure 7 shows the main entry area into the facility.

The megastructure at St. Jean was designed as a training facility. Therefore, its configuration does not represent standards of "unit integrity" found in the U.S. Army. Of course, the 780 recruits housed in the towers labeled "F" in Figure 1 maintain traditional Army organizational units. As the following examples further illustrate, *composite buildings can support unit integrity.*



*a. Eastern view.*



*b. View of quarters.*

*Figure 2. Exterior views of the Canadian Forces megastructure.*



*a. Typical classroom.*



*b. Library.*

*Figure 3. Interior views of the Canadian Forces megastructure.*

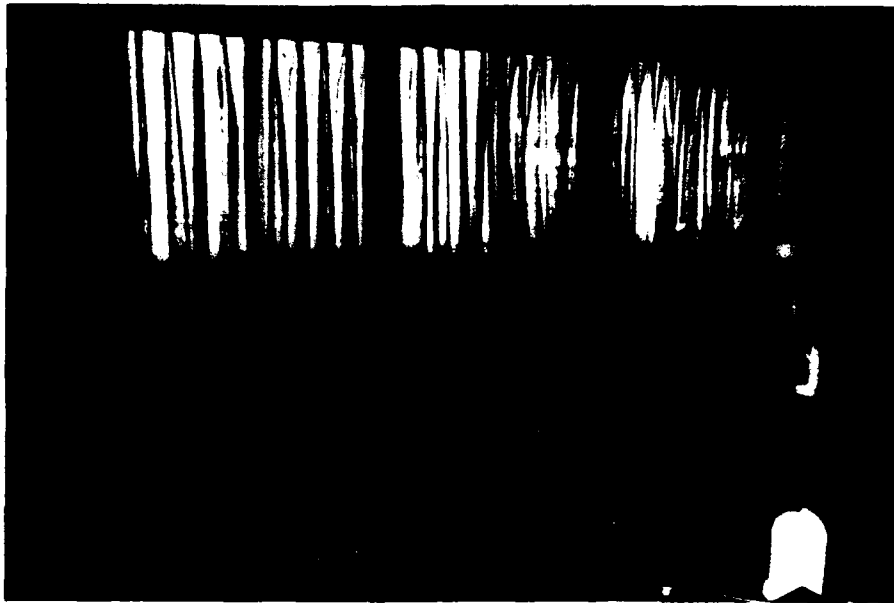


*a. Patio accessible from a dining area.*



*b. A dining facility.*

*Figure 4. Public areas in the Canadian Forces megastructure.*



*a. Transient VIP quarters.*



*b. Recruit barracks.*

*Figure 5. Residential areas in the Canadian Forces megastructure.*



*Figure 6. Mechanical space on the third floor of the Canadian Forces megastructure.*



*Figure 7. Entrance atrium to the Canadian Forces megastructure.*

## A COMMUNITY CENTER-SHOPPING MALL

Fort Wainwright, Alaska, has a winter design temperature of  $-47^{\circ}\text{F}$  and has 14,345 design annual heating degree-days. For comparison, the District of Columbia has equivalent figures of only  $14^{\circ}\text{F}$  and 4211 heating degree-days. Because addition of the 6th Infantry Division represents approximately a *doubling* of troop population, Fort Wainwright is scheduled to receive larger, more efficient community amenities, including the following separate buildings: commissary, post exchange, class VI (liquor) store, clothing sales store, child care center, fast food, bank, credit union, bowling center, indoor ice rink, morale support center, theater, skill development-auto crafts, library, arts and crafts center, physical fitness center, and Alaskan display-seasonal vendors.

In the private commercial sector, most of these functions would be likely to occur in an enclosed mall. As is true for the lower 48 states, *enclosed* malls are much more successful in Alaska than open-faced strip malls. However, the Army seldom employs the mall concept for commercial construction. In this case, the Corps of Engineers decided to study the desirability of housing the above uses in an enclosed mall, rather than in 17 separate buildings.

Livingston-Slone, Inc. (1987) conducted the study that compares the benefits of an enclosed shopping mall-community center for Fort Wainwright, Alaska, with those of 17 individual buildings. Comparisons between the composite building and conventional building alternatives include first costs, operations and maintenance costs, life-cycle costs, construction times, and benefits to the soldiers and their families.

The study demonstrated that the composite shopping mall-community center would increase community interaction and would offer soldiers and their families important relief from winter isolation in barracks and homes. The combination of the physical fitness center, shopping and community center in one building (Fig. 8) would greatly increase the opportunities for informal contact among residents of Fort Wainwright over those available to them from 17 widely separated buildings. The simple convenience of not having to travel by vehicle in  $-40^{\circ}\text{F}$  cold between activities is a major advantage of the composite building concept (Fig. 9).

The composite building would save money, energy and land. It would be 7% less expensive to

build, have a 12% lower operation and maintenance cost, require 15% less steam heat, and occupy 22% less land than the 17 conventional buildings (Table 1). The two concepts entail similar amounts of new construction and use of existing buildings. Existing and planned roads and utilities will adequately serve either alternative.

Compared to the 17 individual buildings, the composite building would increase the morale of soldiers and their families considerably. The composite building would make going out *convenient, sociable and fun*, whereas the 17 conventional buildings require access to a vehicle, discourage social contact and would make leaving home a chore. A well-designed composite shopping mall-community center would provide a much-needed social focus for the base.

## SHOULD COMPOSITE BUILDINGS BE USED FOR MOBILIZATION?

Mobilization requires buildings that are almost instantly available. Troop populations rise quickly at Army bases before they are deployed to their ultimate destinations. Both conventional and composite building construction fail to meet the requirements for speed of construction in many cases. Some alternative technology will be necessary to satisfy the need for rapid troop billets.

Mobilization in World War II left a legacy of buildings that far outlasted their intended lifetime at significant costs for operation and maintenance. *Temporary buildings risk becoming permanent* the next time mobilization occurs. Planners should consider which building types might have a continuing use after mobilization. Such building uses may lend themselves to incorporation into a composite building. Therefore, the Fort Leonard Wood and Alaska studies consider the relative merits of standard mobilization designs (M-designs) and composite buildings in case certain M-design buildings might remain past mobilization.

The two studies comparing M-designs to composite buildings encompass mildly and extremely cold climates. They also include FORSCOM and TRADOC mobilization requirements. Because the studies were carried out differently, each will receive separate attention in what follows. The results are presented according to the points of comparison outlined in the *Introduction*.

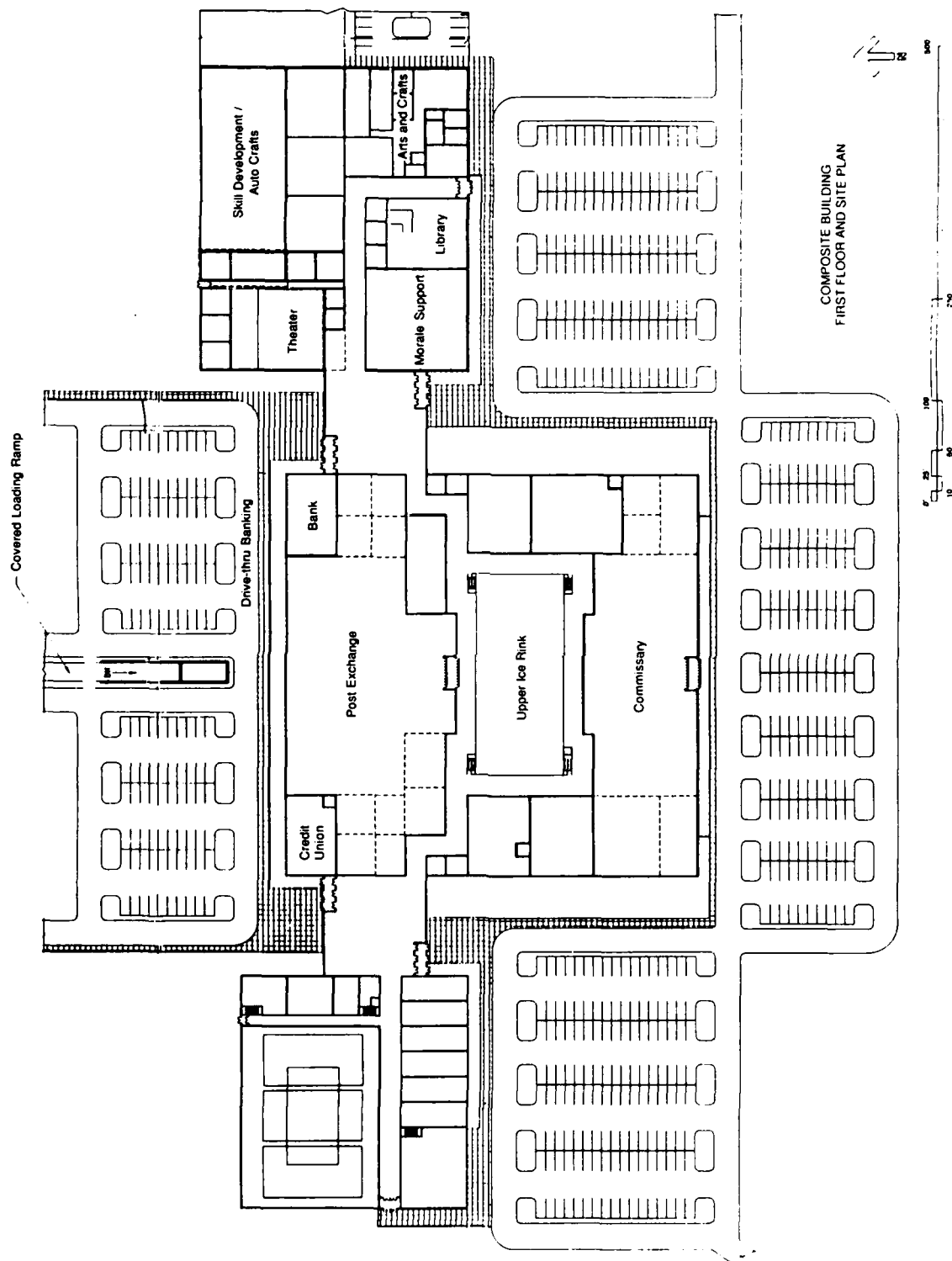


Figure 8. Plan of the shopping mall-community center (after Livingston-Slone 1987).

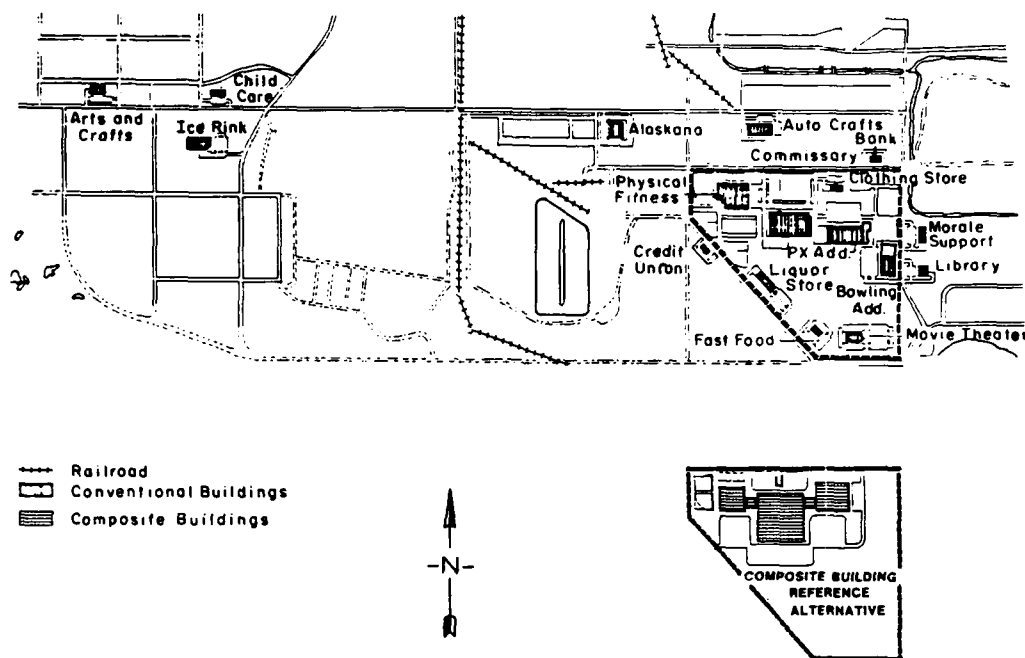


Figure 9. Siting of shopping mall-community center in comparison with the siting of the 17 separate buildings (after Livingston-Slone 1987).

Table 1. Comparison of areas, costs and energy usages between the composite shopping mall-community center and the 17 equivalent, separate buildings.

|                    | Areas                      |                                | Costs                |                                       | Energy use               |                                  |
|--------------------|----------------------------|--------------------------------|----------------------|---------------------------------------|--------------------------|----------------------------------|
|                    | Site<br>(ft <sup>2</sup> ) | Building<br>(ft <sup>2</sup> ) | Construction<br>(\$) | Operation &<br>maintenance<br>(\$/yr) | Steam<br>(million lb/yr) | Electricity<br>(million W hr/yr) |
| Composite building | 1,800,000                  | 465,000                        | 62,703,470           | 2,615,615                             | 55.176                   | 23,900                           |
| Separate buildings | 2,369,850                  | 460,000                        | 67,131,340           | 2,924,955                             | 72.731                   | 23,031                           |

## COMPOSITE BUILDINGS FOR MOBILIZATION IN ALASKA

USKH, the architecture and engineering firm that framed the 6th Infantry Division (Light) mobilization plan, prepared a study (USKH 1986) of composite building concepts for mobilization. The study compares three concepts: a conventional M-design, multi-building battalion block (Fig. 10), a composite battalion block where all needs are provided for in one building (Fig. 11), and a hybrid battalion block that employs M-design barracks but combines nonresidential functions in one building, the "composite-core" (Fig. 12).

The M-design buildings are of conventional frame construction intended for sites throughout the U.S. Fire safety requires that the composite and composite-core buildings be of permanent construction.

Figures 11b and c show how residential wings might radiate from the central portion of the composite building. The central part would contain the battalion administration and headquarters functions, a classroom and dining room, and storage facilities. In the hybrid block (Fig. 12) the composite-core would house these same nonresidential facilities.

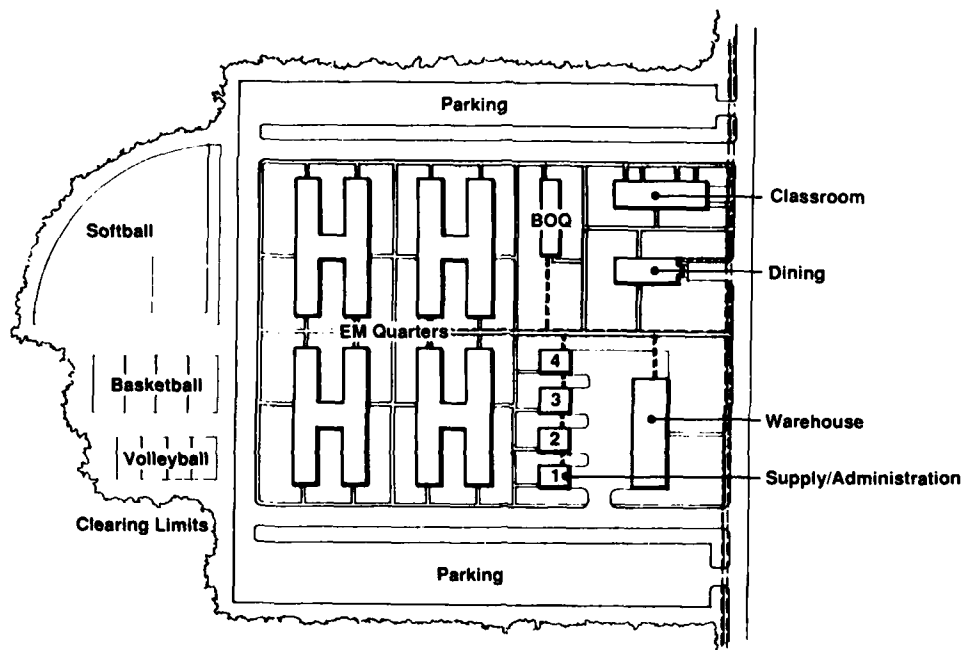


Figure 10. M-design battalion block for Alaska (after USKH 1986).

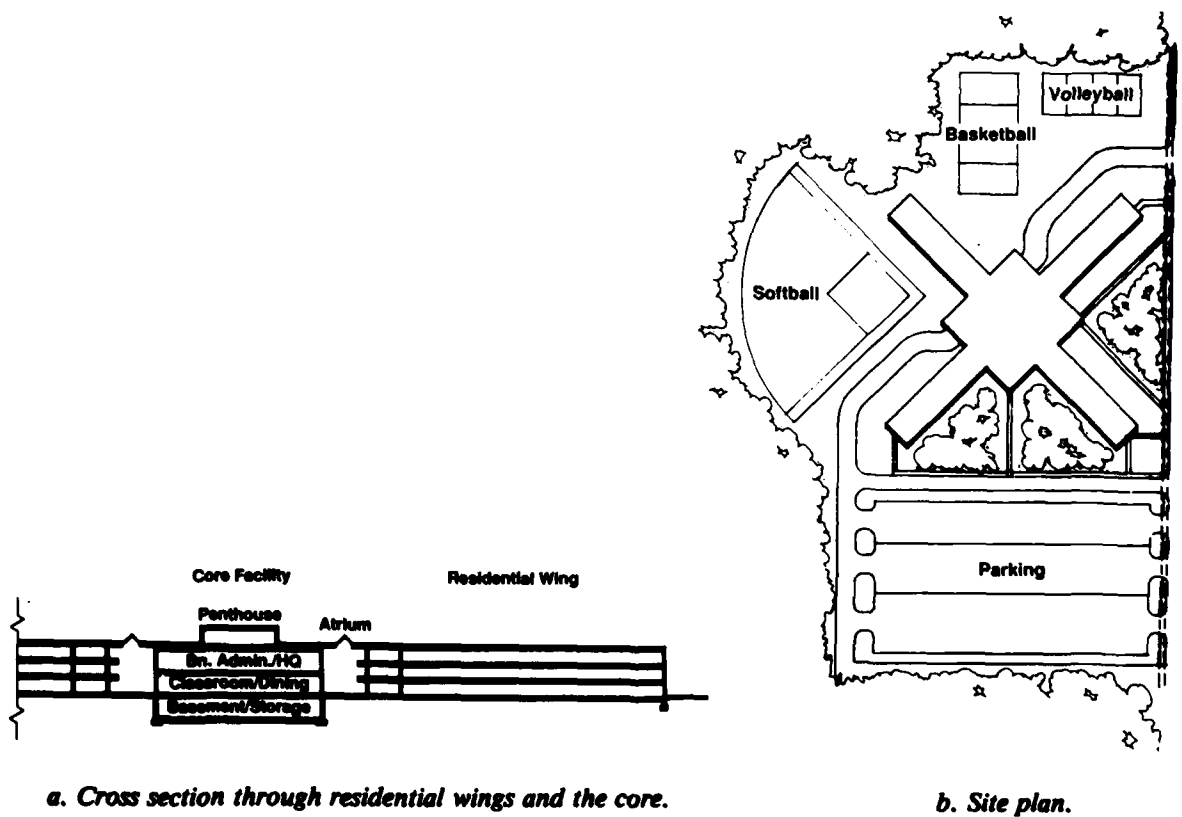
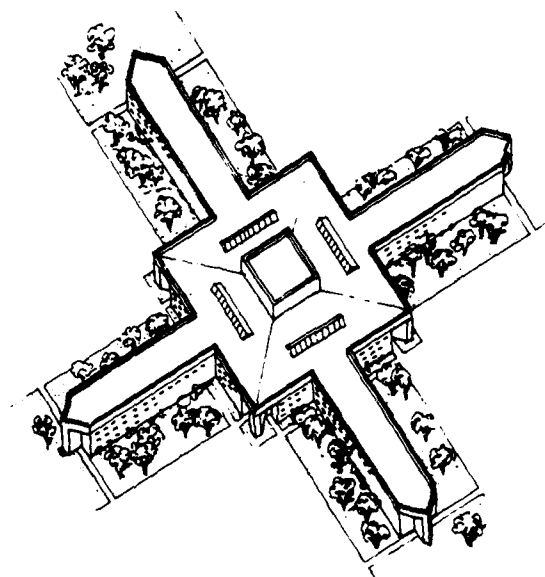
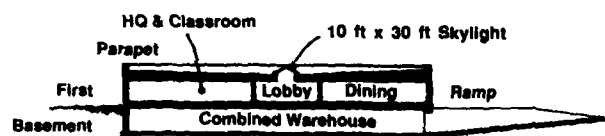


Figure 11. Composite battalion block for Alaska (after USKH 1986).

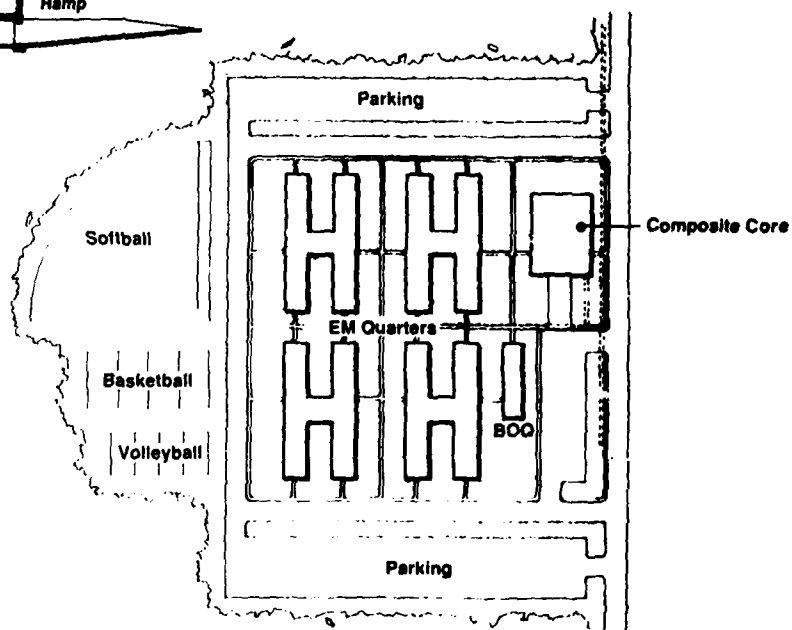


c. Axonometric view.

Figure 11 (cont'd). Composite battalion block for Alaska (after USKH 1986).

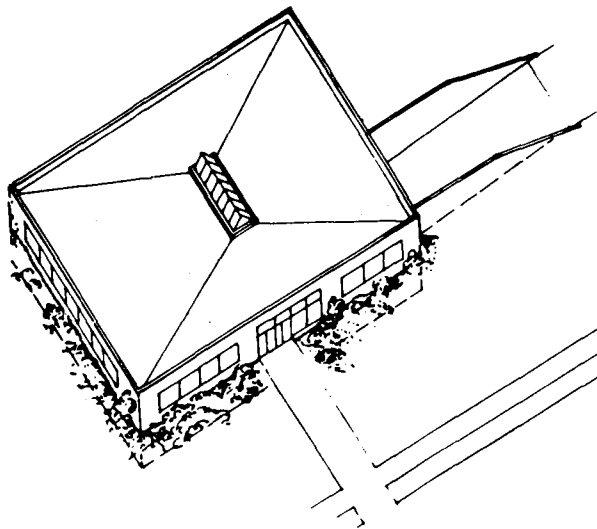


a. Cross section.



b. Site plan.

Figure 12. Hybrid battalion block, combining M-design barracks with a composite-core building for non-residential uses (after USKH 1986).



*c. Axonometric view.*

*Figure 12 (cont'd).*

## **Manner of construction**

### ***Sitework***

The site was assumed to be relatively flat, without significant deposits of permafrost or moisture-rich soils, with a low water table and close to existing roads and utilities. The roadway, sidewalk, utility trenching, utilidors and their connections were assumed to be identical for each concept (USKH 1986).

### ***Foundations***

Foundations were assumed to include conventional spread concrete footings on non-frost-susceptible gravel replacement fill. Footings and foundation walls would be cast-in-place reinforced concrete with bituminous damp-proofing.

### ***Structural frame***

The M-design buildings comprise wood-framed walls with plywood diaphragms and shearwalls, except for the combined warehouse, which is of wood pole and braced frame construction. Roofs are wood trusses.

The structural system for the composite building and for the composite-core building would meet a Type II construction criterion with 1-hour fire protection. The columns, beams and bracing would be standard rolled steel sections. The roof and floor systems would comprise steel joists and a steel and concrete composite deck.

### ***Building envelopes***

The M-design buildings have plywood siding and wood-stud exterior walls. Roofs are sheathed with plywood and covered with composition shingles. The insulation is 3½-in. Fiberglas in both the walls and attic. This is considered to be inadequate for the Alaskan climate, but was retained in the USKH study. Over the projected 25-year physical lifetime of the facilities, the shingle roofs would probably require at least one replacement because of damage from wind, temperature extremes and glaciation.

The composite and composite-core buildings employ metal stud framing attached to the steel structural frame with 3½-in.-thick Fiberglas batt insulation, gypsum sheathing, building paper, horizontal wood furring and factory-finished metal cladding. The horizontal wood furring would provide a thermal break between the cladding and the steel studs and framing. The insulating value of this wall system was assumed to be equal to that of the M-designs for the purposes of the study. The prefinished metal cladding has been chosen to avoid exterior painting over the design life of the building.

The composite and composite-core buildings would have a protected roof membrane system. Properly designed and constructed, this system can be maintenance-free over the intended life-span of the project.

Interior partition framing would be wood studs in the M-design buildings and metal stud walls in the composite and composite-core buildings, both with gypsum wallboard finish.

#### *Mechanical systems*

Energy for heating would be provided by central steam entering the facilities via buried utilidor or utiliduct.

The standard M-design buildings would employ forced-air heat.

The residential wings of the composite facility would employ hydronic baseboard heat with operable windows for ventilation. Both the core area of the composite building and the composite-core building would use a variable air-volume system for both heat and ventilation.

Heat recovery would have been desirable for the dining and kitchen areas, but was not considered in the study.

#### *Electrical systems*

Electrical distribution would be via service entrances from utilidors. The M-design or hybrid options would require separate entrances for each building. The composite building would require only a single service entrance.

The M-design buildings could use a Romex-type wiring for secondary power distribution, whereas the composite building and composite-core building would run all conductors within conduit or other approved raceways.

#### **Initial cost comparisons**

##### *Battalion blocks*

The USKH study compares the first costs for the three concepts, assuming similar construction costs in Anchorage and Fairbanks. Table 2 shows a 28% higher cost to build the battalion block with a composite building of permanent construction, despite site costs that are only half those of the

**Table 2. Construction costs of battalion blocks for mobilization in Alaska (millions of dollars).**

|           | <i>M-design</i> | <i>Composite</i> | <i>Hybrid</i> |
|-----------|-----------------|------------------|---------------|
| Sitework  | 2.0             | 0.9              | 1.5           |
| Buildings | 14.9            | 20.7             | 15.5          |
| Totals    | 16.9            | 21.6             | 17.0          |

conventional M-design block. The hybrid scheme has essentially no cost penalty, lower sitework costs offsetting the slightly higher cost of building construction.

#### *Nonresidential facilities*

Table 3 compares the costs of constructing the nonresidential portions of the block, using the M-design and the composite-core hybrid schemes. The M-design sitework is almost three times more costly than the sitework for the hybrid building, thus minimizing the cost advantage of the M-design's frame construction.

These figures demonstrate that if the conventional M-design buildings were of permanent construction, *the composite-core building alternative would be less expensive.*

**Table 3. Construction costs of nonresidential buildings for mobilization in Alaska (millions of dollars).**

|           | <i>M-design</i> | <i>Hybrid</i> |
|-----------|-----------------|---------------|
| Sitework  | 0.76            | 0.25          |
| Buildings | 2.65            | 3.31          |
| Totals    | 3.41            | 3.57          |

#### **Life-cycle cost comparisons**

The USKH study based its life-cycle cost assumptions on the Federal Energy Management Program guidelines, except for energy life-cycle costs that were included in the software of the TRACE\* computer analyses done by USKH. The discount rate was assumed to be 10% and the project life 25 years.

##### *Battalion blocks*

The life-cycle costs in the USKH study were different for Fort Wainwright and Fort Richardson, although the conclusions were the same. The differences arise out of the fuel costs and climates for each base. Table 4 shows the life-cycle costs for the battalion block, built as M-designs, a composite building, or a hybrid of the two concepts, as before. The USKH study assumed similar levels of insulation in frame and permanent construction,

\* TRACE—a building energy usage simulation program by the Trane Company.

**Table 4. Life-cycle costs of battalion block for mobilization in Alaska (millions of dollars).**

|                        | <i>M-design</i> | <i>Composite</i> | <i>Hybrid</i> |
|------------------------|-----------------|------------------|---------------|
| <b>Fort Richardson</b> |                 |                  |               |
| Initial                | 16.93           | 21.61            | 17.06         |
| Energy                 | 2.00            | 1.83             | 1.96          |
| Annual O&M*            | 0.66            | 0.50             | 0.57          |
| Other O&M              | 0.36            | 0.32             | 0.35          |
| Totals                 | 19.95           | 24.26            | 19.94         |
| <b>Fort Wainwright</b> |                 |                  |               |
| Initial                | 16.93           | 21.61            | 17.06         |
| Energy                 | 2.68            | 2.12             | 2.54          |
| Annual O&M             | 0.66            | 0.50             | 0.57          |
| Other O&M              | 0.36            | 0.32             | 0.35          |
| Totals                 | 20.63           | 24.55            | 20.52         |

\* Operation and maintenance.

so energy savings reflect differences in surface area only.

Table 4 demonstrates that the composite block will have only 88% of the downstream costs of the M-design block at Fort Richardson. At Fort Wainwright the downstream costs will be only 79% of the M-design costs. Its energy bill would be about 8% less at Fort Richardson and at least 20% less at Fort Wainwright. But in this comparison with frame buildings it still costs about 20% more over the project lifetime because of the initial costs of its permanent construction.

The life-cycle cost comparison for the three schemes favors the hybrid option.

#### *Nonresidential facilities*

Table 5 shows the life-cycle cost comparison for the nonresidential buildings alone. The costs for the hybrid are about the same as those for the M-design. As in Table 4, if the comparison were between conventional and composite-core permanent construction, then *life-cycle costs for the composite-core building would be significantly less.*

Table 5 shows that the downstream costs for the composite-core buildings would be 18% less than the costs for the equivalent M-design buildings. Energy costs would be 11% higher for the M-design alternative at Fort Richardson and 32% higher at Fort Wainwright.

**Table 5. Life-cycle costs of non-residential buildings for mobilization in Alaska (millions of dollars).**

|                        | <i>M-design</i> | <i>Hybrid</i> |
|------------------------|-----------------|---------------|
| <b>Fort Richardson</b> |                 |               |
| Initial                | 3.41            | 3.57          |
| Energy                 | 0.39            | 0.35          |
| Annual O&M*            | 0.16            | 0.07          |
| Other O&M              | 0.05            | 0.05          |
| Totals                 | 3.98            | 4.04          |
| <b>Fort Wainwright</b> |                 |               |
| Initial                | 3.41            | 3.57          |
| Energy                 | 0.54            | 0.41          |
| Annual O&M             | 0.16            | 0.07          |
| Other O&M              | 0.05            | 0.05          |
| Totals                 | 4.06            | 4.10          |

\* Operation and maintenance.

#### **Speed of construction comparison**

The USKH (1986) study rates the speed of construction for the three concepts on a scale of 0 to 100 as follows, with the M-design frame building method being the fastest:

|           |     |
|-----------|-----|
| M-design  | 100 |
| Composite | 90  |
| Hybrid    | 95  |

The time-to-construct criterion should be 180 days. This is an especially difficult and costly goal if that time period occurs during the winter in Alaska. The normal construction season in both the Anchorage and Fairbanks areas usually constrains sitework, foundations and closing-in to be completed prior to winter. The interior work can then proceed after freezeup.

The wood-frame M-design buildings would lend themselves well to accelerated construction. The steel-framed structures of both the composite building and the composite-core would require a well-orchestrated project management plan to accelerate the construction to meet the 180-day deadline. The following measures would shorten the construction of the steel-framed buildings:

1. Shop drawings prepared in advance (30-day savings).
2. Site preparation prior to construction.
3. Stockpiling of critical components (mechanical/electrical items).

USKH suggests that whether or not the projects must be competitively bid on a non-proprietary basis has a large effect on the time of the overall project.

#### Materials availability comparison

The USKH study ranked the three concepts according to their use of strategic materials, as follows (with the least use of such materials receiving the highest score):

|           |     |
|-----------|-----|
| M-design  | 100 |
| Composite | 50  |
| Hybrid    | 75  |

The scores are attributed as follows:

- 100 = no steel or concrete above the foundation
- 75 = 25% steel or concrete
- 50 = 50% steel or concrete
- 25 = 75% steel or concrete
- 0 = All steel or concrete.

#### Energy efficiency comparison

Energy consumption is an important consideration for facilities that may be in use long after mobilization has ended. During mobilization, lower energy consumption means lower demands on scarce petroleum products. The USKH study showed that a composite building would consume only 41% of the energy required to run the M-design buildings in Fairbanks and only 52% in Anchorage.

The composite-core buildings in the hybrid concept would consume only 27% and 32% of the energy of the M-design counterpart in Fairbanks and Anchorage, respectively. The composite-core buildings would have vastly reduced surface area compared with the nonresidential M-design buildings. The USKH study assumed the insulating value of the two construction types to be essentially equal.

#### Fire and life safety comparison

The Uniform Building Code requires that all structures of the occupancies in this study that are over two stories in height or 3000 ft<sup>2</sup> be 1-hour fire rated throughout. USKH chose the construction type, described earlier, that conforms to a Type II, 1-hour rating. Other alternatives, including heavy timber, were rejected as too costly. The M-design buildings are of Type V-1 construction.

USKH ranked the three concepts as follows for fire and life safety:

|           |     |
|-----------|-----|
| M-design  | 50  |
| Composite | 100 |
| Hybrid    | 75  |

where 100 = intrinsically safe

75 = exceeds generally accepted standards

50 = meets generally accepted standards

25 = may require a variance from one or more standards

0 = intrinsically unsafe.

#### Organizational efficiency comparison

USKH estimated the average daily walking required by the layout of each building concept and ranked the three as follows:

|           |    |
|-----------|----|
| M-design  | 25 |
| Composite | 75 |
| Hybrid    | 50 |

Where the daily walking required is:

- 100 = less than 5 minutes
- 75 = 5-10 minutes
- 50 = 10-15 minutes
- 25 = 15-20 minutes
- 0 = more than 20 minutes.

#### Incremental or modular construction

The USKH study chose the battalion level of organization as the starting point for considering a composite building. Consequently, considerations for changing building capacity were not strong.

#### Habitability comparison

USKH compared the habitability of the three concepts as follows:

|           |    |
|-----------|----|
| M-design  | 25 |
| Composite | 75 |
| Hybrid    | 50 |

These rankings pertained both to a scale rating the availability of privacy and opportunities for social interaction and to a scale rating aesthetics as follows.

#### Habitability

- 100 = high availability of both privacy and social settings
- 75 = some privacy, many social settings
- 50 = some social settings, some privacy
- 25 = some social settings, no privacy
- 0 = no social settings or privacy.

#### Aesthetics

- 100 = building capable of imaginative treatment
- 75 = building can be improved by treatment
- 50 = neutral
- 25 = negatively utilitarian
- 0 = oppressive.

The open dormitory bays of the enlisted men's quarters in the M-design battalion block afford no privacy. The disconnected buildings provide no social settings, except for the dining facility.

The hybrid concept retains the lack of privacy in the quarters, but increases interaction in the composite-core building with the lobby that serves the classroom and dining functions.

The composite building would have separate rooms similar to the current practice in the Army, so privacy would be increased over using the M-design open-bay quarters. Social interaction would be increased by the existence of the atrium space, which funnels people toward the center of the facility. The increased chance of informal encounters among people of all ranks enhances the sense of community in the battalion, as happens at the post office or general store in a small town.

### **Recommendations**

The USKH study examined three alternatives for accommodating mobilization at Fort Richardson and Fort Wainwright. They were using the standard M-designs (Fig. 10), using a composite building of permanent construction (Fig. 11), or a mixture of M-design barracks and a composite-core building housing nonresidential uses in a hybrid arrangement (Fig. 12).

The results of the study favor using the hybrid option for several reasons:

1. The composite-core building is likely to be useful after mobilization.
2. The first costs for the composite-core building are about equal to the corresponding M-design buildings.
3. The life-cycle costs are also about equal.
4. The composite-core building uses much less energy.
5. The hybrid approach allows barracks to be built rapidly, yet results in an enduring non-residential building.

These results suggest that composite buildings should be considered for large-scale basing in Alaska that requires new construction.

### **COMPOSITE BUILDINGS FOR MOBILIZATION AT FORT LEONARD WOOD, MISSOURI**

The Campbell Design Group (1986) prepared a study of composite building concepts for mobilization at Fort Leonard Wood, Missouri, which ex-

periences mildly cold winters. As with the Alaska study, this study compares composite building concepts with the standard M-design approach. The composite building concepts could include the use of composite buildings exclusively, or mixing nonresidential composite buildings with M-design barracks, as in the USKH study. Mixing uses was not treated explicitly in the Campbell Design Group study.

The mobilization plan calls for building 36 new 288-person barracks and five new 360-person barracks. It is widely recognized that M-design barracks cannot be built fast enough to meet the population load during the buildup phase of mobilization.

The Campbell Design Group study identified 11 building requirements that would lend themselves to consolidation within composite buildings:

1. Unit headquarters-administration facilities.
2. Barracks.
3. Dining facilities.
4. Medical-dental facilities.
5. Storage facilities.
6. Classroom facilities.
7. Unit chapel.
8. Skill development center.
9. Exchange branch.
10. Theater.
11. Physical fitness center (gymnasium).

The study groups these uses into three categories of composite building: barracks-company, battalion and regimental-brigade. Each barracks (not illustrated) would accommodate 576 men in a two-story H layout, incorporating company administration and supply functions. The battalion composite building (Fig. 13) would incorporate dining areas, classrooms, offices, physical fitness areas and a warehouse. The regimental-brigade composite building (Fig. 14) incorporates headquarters functions and a dental clinic on the second floor. The first floor includes a health clinic, a dining area, applied instructional bays, an auditorium-chapel and storage-utility areas. These buildings would be similar in scale and construction to public schools or supermarkets.

The current mobilization master plan for Fort Leonard Wood envisions two separate cantonment areas (Fig. 15). The composite building site plan from the Campbell Design Group study would require significantly less area on one of the cantonment areas (Fig. 16). Each layout accommodates three brigade complexes.

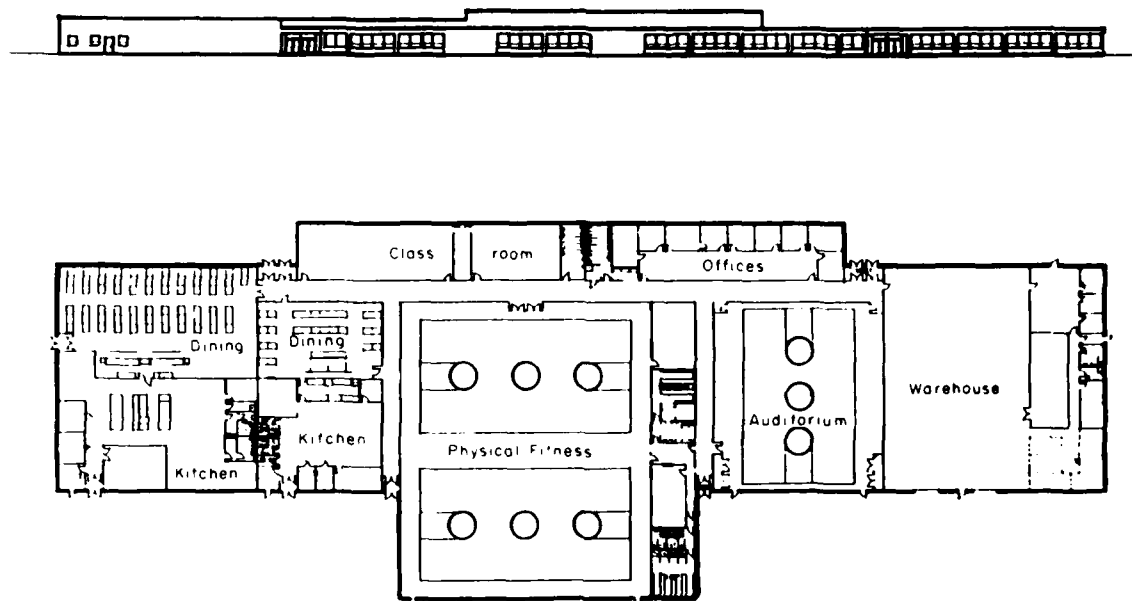
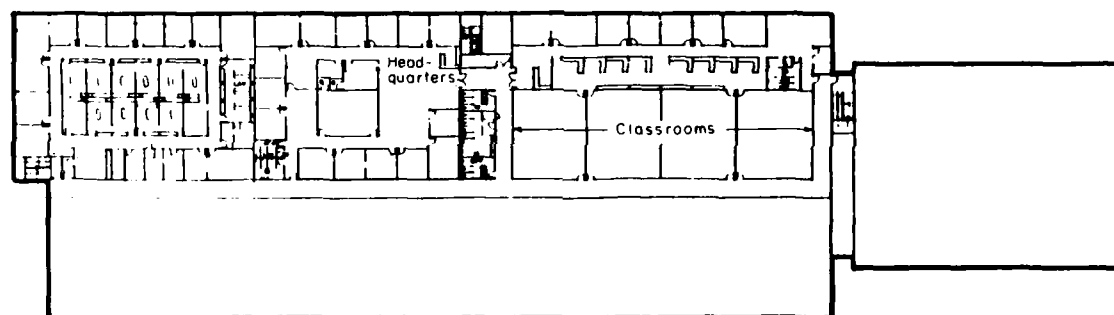
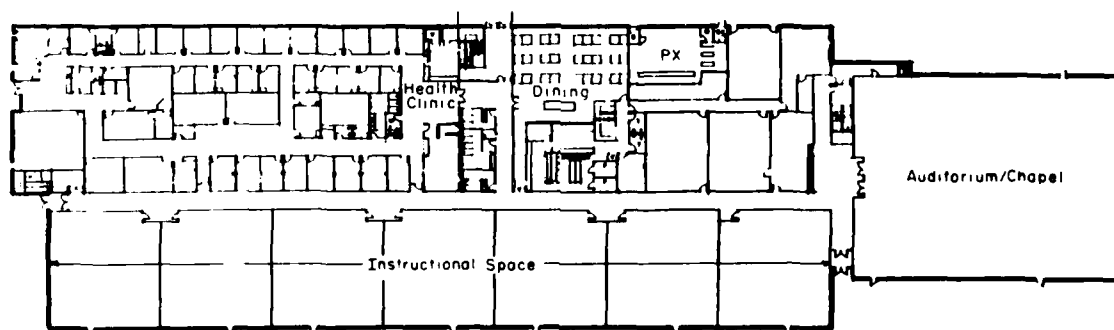


Figure 13. Battalion composite building for Fort Leonard Wood (after Campbell Design Group 1986).



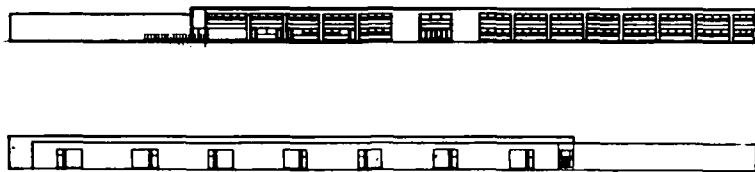
## SECOND FLOOR



## FIRST FLOOR

a. Plan view.

Figure 14. Regimental-brigade composite building for Fort Leonard Wood (after Campbell Design Group 1986).



b. Front and rear views.

Figure 14 (cont'd).

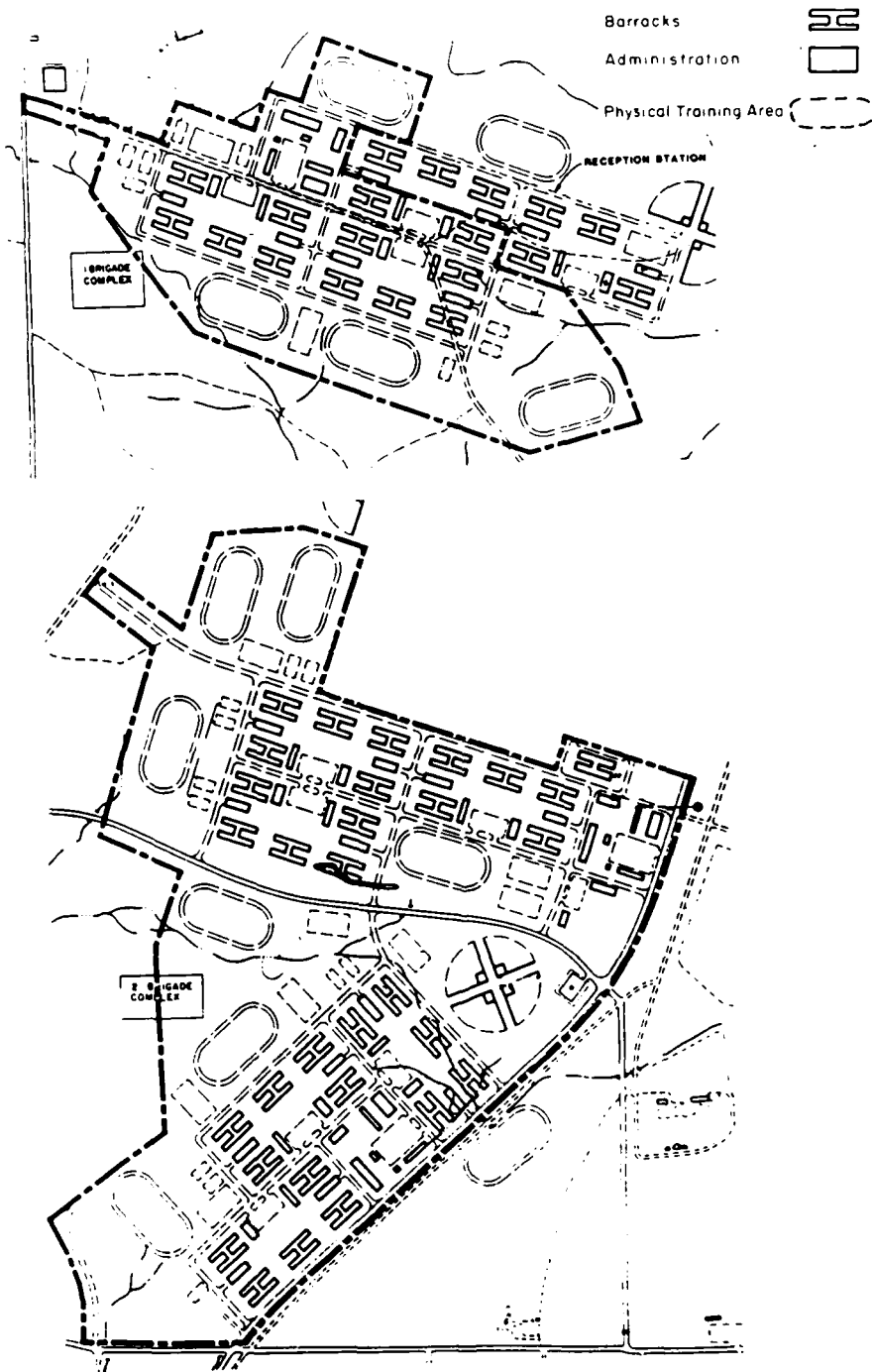
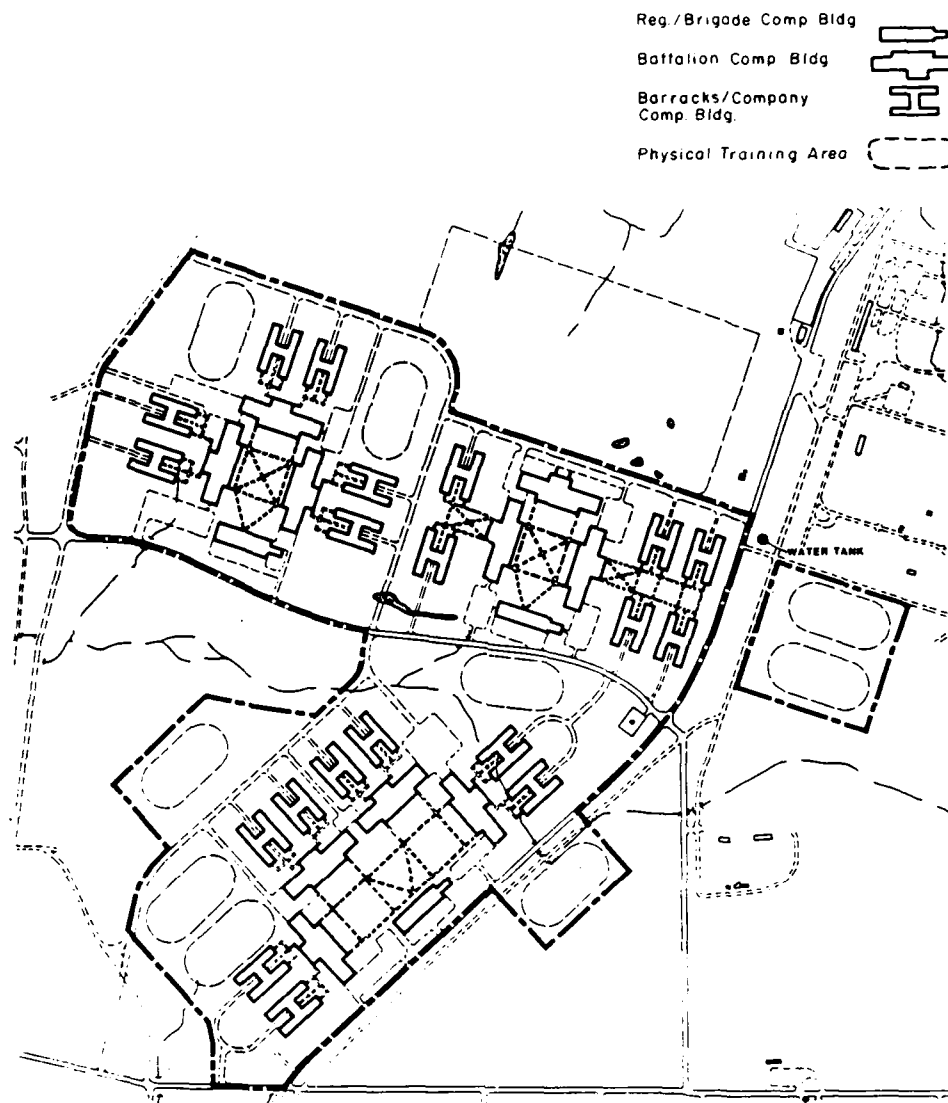


Figure 15. Site plan for M-design mobilization buildings at Fort Leonard Wood (after Campbell Design Group 1986).



*Figure 16. Site plan for composite mobilization buildings at Fort Leonard Wood (after Campbell Design Group 1986).*

#### **Manner of construction**

Typical construction for the battalion and regimental-brigade buildings is shown in Figure 17. The barracks-company buildings are different, with their concrete block walls and pitched asphalt shingle roofs.

#### **Sitework**

The site chosen for mobilization construction is reasonably flat. The method for constructing roadways and utilities would be identical in both concepts, so the costs involved would reflect the quantities and not the qualities of each item.

#### **Foundations**

The foundations are assumed to be conventional spread footings for the M-design buildings and the composite barracks-company buildings. Non-residential composite buildings had slab on grade foundations, with a concrete grade beam. Columns rest on reinforced footings.

#### **Structural frames**

The M-design buildings comprise wood framing, as explained earlier.

Composite barracks-company buildings have concrete block bearing walls. The nonresidential

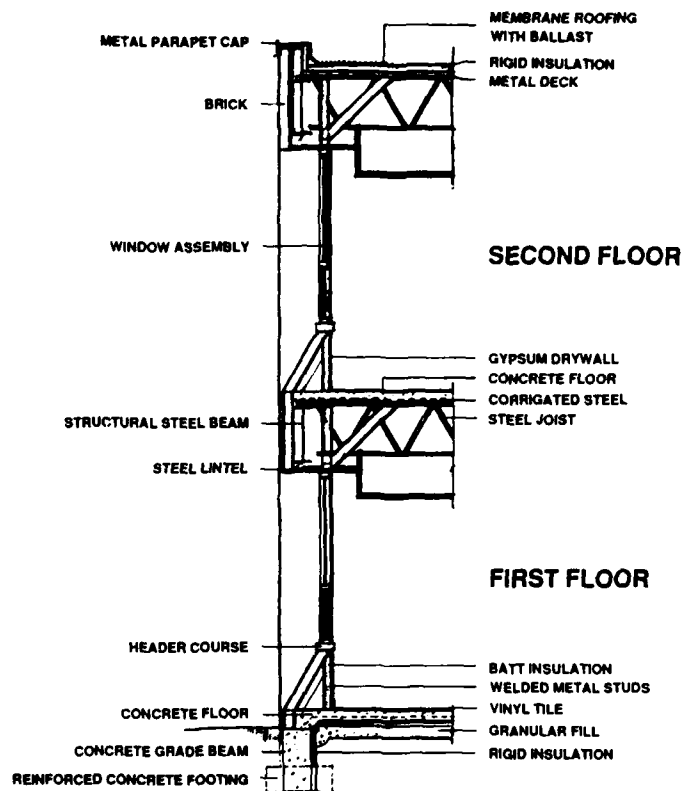


Figure 17. Typical cross-section detail for regimental-brigade buildings at Fort Leonard Wood (after Campbell Design Group 1986). Battalion buildings have an identical cross section, minus the second floor.

composite buildings have A-36 standard steel shapes for columns, beams and purlins. Their floor and roof framing are open-web (H-series) steel joists. Long spans for the physical fitness center are steel trusses or rigid frame.

#### Building envelopes

The M-design buildings comprise plywood sheathing and asphalt shingles on roofs, as described earlier. The walls and attic would contain 2½ in. of Fiberglas insulation. Heat transmission values are 0.10 for the walls, 1.13 for windows and 0.08 for roofs (Btu/hr ft<sup>2</sup> °F).

The composite barracks-company buildings have textured 12-in. masonry bearing walls with vermiculite insulation. The nonresidential composite buildings have 4-in. brick veneer walls with a 6-in. Fiberglas insulation and gypsum drywall. At auditoriums, physical fitness centers, storage and instructional bays, the walls contain 1-in. rigid insulation over masonry block with a brick veneer.

Roofs are corrugated metal with 2-in. insulation and a membrane with ballast on the nonresidential composite buildings. The barracks-company composite buildings have plywood sheathing with felt and heavy-weight asphalt shingles. Second floors have a corrugated metal deck with a concrete composite slab.

Assumed design transmission factors are 0.05 for the walls, 0.11 for the roofs and 1.13 for glass (Btu/hr ft<sup>2</sup> °F).

Interior partitions would be wood studs in the M-design buildings and in the composite buildings masonry block or metal-framed gypsum drywall, depending on fire-safety requirements.

#### Mechanical systems

Energy for heating would be provided by natural gas for all buildings.

The standard M-design buildings would employ forced-air heat.

The regimental-brigade composite buildings would have a system of hot water boilers. These would supply coils in air-handling units. The air-handling units serving the clinics would use direct expansion cooling, with air-cooled condensers adjacent to the building. All air-handling units would incorporate an economizer cycle with the temperature control system.

The battalion headquarters composite buildings would be heated with a series of forced-air furnaces that incorporate an economizer cycle for outside air cooling in the spring and fall. These would have no air conditioning.

The barracks-company composite building would employ hydronic baseboard heating. The windows would supply needed ventilation, supplemented with a mechanical exhaust system for summer cooling and separate exhausts in the shower and toilet areas.

#### **Initial cost comparisons**

The Campbell Design Group study did not explicitly address the hybrid option treated in the USKH study, of employing M-design barracks and composite nonresidential buildings. Therefore, the following comparisons required remanipulating the published data to make them comparable to those in the Alaska study. Site costs were assigned to residential and nonresidential buildings in proportion to the areas of each building type.

#### **Complete brigade complexes**

Table 6 shows that although the composite building concept requires only 62% of the site development costs of the M-design buildings, the higher-quality permanent construction offsets those savings by 23% for the total cost. Mixing composite nonresidential buildings with M-design barracks in the hybrid option still incurs an 11% cost penalty.

#### **Nonresidential facilities**

Table 7 compares the costs of constructing the *nonresidential* portions of the brigade complexes, comparing the battalion and regimental-brigade composite buildings with the corresponding M-design buildings. As before, a 34% savings in site preparation costs does not offset the 25% penalty for total construction cost.

The M-design, composite and hybrid alternatives have similar floor areas; only the costs per square foot differ. Therefore, sitework costs would suggest that if the conventional M-design buildings were of permanent construction, the

**Table 6. Construction costs of three brigade complexes for mobilization in Missouri (millions of dollars).**

|           | <i>M-design</i> | <i>Composite</i> | <i>Hybrid</i> |
|-----------|-----------------|------------------|---------------|
| Sitework  | 4.09            | 2.53             | 3.84          |
| Buildings | 99.77           | 125.36           | 110.95        |
| Totals    | 103.86          | 127.89           | 114.79        |

**Table 7. Construction costs of nonresidential buildings for mobilization in Missouri (millions of dollars).**

|           | <i>M-design</i> | <i>Hybrid</i> |
|-----------|-----------------|---------------|
| Sitework  | 0.74            | 0.49          |
| Buildings | 43.05           | 54.23         |
| Totals    | 43.79           | 54.72         |

*composite building alternatives would be less expensive.*

#### **Life-cycle cost comparisons**

The life-cycle cost assumptions in the Campbell Design Group report included a 7% discount rate, a 25-year economic design life and energy price escalation factors published by the Department of Energy. A salvage value of one-third of the construction cost at 25 years, discounted to present worth, was assumed for the composite buildings.

#### **Complete brigade complexes**

Thanks to an energy requirement of only 52% of that for the M-design buildings, the life-cycle costs for the composite building approach incurred only a 3% penalty (Table 8). The hybrid option incurred about the same penalty by exchanging lower first costs for higher energy costs.

The downstream costs for the composite building alternative are only 55% of those of the M-design buildings. For the hybrid concept the downstream costs are reduced only 19%.

#### **Nonresidential facilities**

Table 9 shows the life-cycle cost comparison for the nonresidential buildings alone. The composite building alternative costs about 7% more than the M-design alternative.

**Table 8. Life-cycle costs of three brigade complexes for mobilization in Missouri (millions of dollars).**

|             | <i>M-design</i> | <i>Composite</i> | <i>Hybrid</i> |
|-------------|-----------------|------------------|---------------|
| Initial     | 103.86          | 127.89           | 114.79        |
| Energy      | 20.18           | 10.49            | 15.51         |
| Annual O&M* | 4.89            | 3.78             | 4.68          |
| Other O&M   | 2.02            | 0.50             | 1.74          |
| Salvage     | ( 0 )†          | ( 7.67)          | ( 1.39)       |
| Totals      | 130.96          | 134.99           | 135.33        |

\* Operation and maintenance.

† Negative cost.

**Table 9. Life-cycle costs of non-residential buildings for mobilization in Missouri (millions of dollars).**

|             | <i>M-design</i> | <i>Hybrid</i> |
|-------------|-----------------|---------------|
| Initial     | 43.79           | 54.23         |
| Energy      | 10.89           | 6.22          |
| Annual O&M* | 0.89            | 0.68          |
| Other O&M   | 0.37            | 0.09          |
| Salvage     | ( 0 )†          | ( 1.39)       |
| Totals      | 55.94           | 59.83         |

\* Operation and maintenance.

† Negative cost.

The downstream costs of the nonresidential composite buildings are only 57% of the corresponding M-design buildings.

#### **Speed of construction comparison**

Both M-design buildings and the composite barracks-company buildings can't be built fast enough to accommodate the programmed troop load under mobilization. The shortfalls at 14 weeks would be 10,477 troop spaces for the M-design buildings and 13,933 spaces for the composite barracks-company buildings.

The M-design buildings could be built by a less sophisticated work force than the composite buildings could be, with a greater chance to interchange skills among the trades, e.g., a plumber could do framing and a carpenter could do rough wiring.

The composite buildings have more sophisticated structural, mechanical, electrical and plumbing systems. Furthermore, more heavy equipment would be required to erect steel, emplace concrete

and install mechanical equipment. The Campbell Design Group study relied exclusively on stock items to minimize the impact of the more elaborate components required in composite buildings.

Composite buildings would be less vulnerable to construction delays due to weather. The greater volume per unit of enclosure for the composite buildings would help ensure that more of their construction time would be indoors.

To achieve the best speed of construction for composite buildings, it would be necessary to assume the following:

1. All equipment and labor would be available from the start of mobilization.
2. There would be shifts in operation 24 hours a day.
3. Each construction crew would specialize in a particular building type and speed would increase after the first building.
4. Site excavation, foundation work and utility installation would take place during above-freezing weather.

The bottom line: *It takes more time to achieve a better building.*

#### **Materials availability comparison**

The Campbell Design Group study foresaw no major difficulties in obtaining the materials necessary for composite buildings. The study estimated that the volume and variety of construction components would be greater for the M-design buildings than for the composite buildings. Therefore, it would be easier to stockpile and retrieve components for composite buildings. Currently, this would require congressional approval.

#### **Energy efficiency comparison**

The M-design and composite buildings were each modeled by Campbell Design, using the TRACE computer program by the Trane Corp.

Overall, the composite buildings use only 40% of the total energy used by the M-designs. Most of the savings occur in the barracks-company composite buildings, which have much lower surface area. The battalion and regimental-brigade composite buildings save only 30% of the energy consumed by M-designs because of the added requirement for air conditioning in the medical clinics. The percentage energy savings differ from the percentage energy dollar savings because of the composite buildings' mixture of electricity for air conditioning the clinics and fuels for heating versus the M-design buildings' use of heating fuels only.

### **Fire and life safety comparison**

Fire codes constrained the composite buildings to a higher quality (and more expensive) type of construction than the M-design buildings. The minimum of Type-II, 1-hour fire rating is intrinsically safer than the frame construction of the M-designs.

### **Organizational efficiency comparison**

The composite buildings consolidate various echelon functions within one building. For example, the battalion composite buildings centralize dining, physical fitness, classroom training and supply functions. The greater compactness of composite buildings could be expected to increase the time available for training of mobilized troops.

### **Incremental or modular construction**

The Campbell Design Group determined that the collection of uses in the battalion and regimental-brigade composite buildings is reasonably complete. A change in program would more probably involve addition or deletion of a battalion rather than addition or deletion of a function requiring building space.

Addition or deletion of an entire M-design building has fewer consequences in planning and design than addition or deletion of an area within a composite building.

### **Habitability comparison**

The corridor structure in both the regimental-brigade and battalion composite buildings assures informal encounters among people of all ranks.

The M-designs scatter activities over a large area. This is time-consuming for pedestrian traffic and diminishes the opportunity for informal contact among the ranks.

### **Recommendations**

The Campbell Design Group study of employing composite buildings for mobilization at Fort Leonard Wood represents two cases: composite buildings in a climate with mildly cold winters and composite buildings for TRADOC. The comparison was between M-design mobilization buildings and the composite buildings illustrated in Figures 10 and 11, as well as a 576-man barracks-company composite building.

Composite buildings will not achieve the mobilization goals of faster construction and lower costs than M-design buildings.

Composite buildings should be considered in place of M-design buildings for Fort Leonard Wood where:

1. The usefulness of the building may outlast mobilization.
2. Lower downstream costs are desirable.
3. Much lower energy consumption is desirable.
4. More efficient and habitable buildings are appropriate.

## **CONCLUSIONS**

Two studies, comparing composite buildings designed for mobilization with the traditional frame construction of the M-design buildings, covered both extremely and mildly cold winter conditions and both FORSCOM and TRADOC uses. The findings of the two studies differed as follows:

1. Initial costs—the sitework savings offset much of the increased cost of more permanent composite building construction in Alaska, but not at Fort Leonard Wood.
2. Life-cycle costs—life-cycle costs for building a hybrid mixture of M-design barracks and nonresidential composite buildings were equal to the costs for a straight M-design approach in Alaska, but not at Fort Leonard Wood.

The studies agreed in the following respects:

1. Speed of construction—composite buildings would take longer to construct than M-design buildings and would require greater construction trade and management skills.
2. Materials availability—composite buildings would rely more heavily on steel and concrete, materials that are more strategically critical than the wood required for the M-design buildings.
3. Energy efficiency—composite buildings would be much more energy efficient, requiring approximately 40% of the energy of the M-design buildings.
4. Fire and life safety—composite buildings are required to meet at least a Type II, 1-hour fire rating, inherently much safer than the frame construction of the M-design buildings.
5. Operational efficiency—composite buildings substantially reduce the time required to walk or drive between functions.

6. Incremental or modular construction—M-designs make addition or deletion of a desired use from the base plan easier.
7. Habitability—composite buildings create more and better opportunities for informal interaction among the ranks, better privacy and are potentially more aesthetic.

## RECOMMENDATIONS

Composite buildings warrant serious consideration in cases where the buildings' usefulness is likely to outlast the period of mobilization. In these cases composite buildings of permanent construction will be cheaper than conventional permanent buildings, both to construct and to maintain. Since M-design buildings can't necessarily accommodate troop influxes on schedule, the measures to compensate for this problem may suffice for composite buildings. A mixture of M-design barracks and composite building nonresidential functions may be worth considering.

These mobilization studies, the shopping mall-community center study, and the experience with the Canadian Forces Base at St. Jean, Quebec, show that composite buildings warrant serious

consideration for major base expansion where winter weather is encountered.

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