CONCRETE DESIGN CENTER

Building Recommendations

for a

Proposed 41,500 sf Four Story Hotel

(For Reference Only)

Richmond, VA

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Appendix 1: Detailed Cost Analysis for Wood Frame Construction

Appendix 2: Detailed Cost Analysis for ICF & Precast Plank Flooring

Appendix 3: Detailed Cost Analysis for ICF & Composite Concrete Flooring Systems

1. Construction Cost Estimate

A comprehensive cost estimate was conducted for a speculative four-story 41,250 square foot hotel located in Richmond, Virginia. The building consists of 88 units, a gym, various offices, and ancillary support spaces. The cost estimates were conducted for wood frame construction and concrete construction. Room furnishings have been included within the estimates. Cost estimates were derived from RS Means, the most widely known and respected cost estimating data available.

The wood frame construction consists of wood frame for all the exterior, corridor, demising and interior walls, floors and roof. The shaft wall for wood is CMU. The concrete construction consists of Insulating Concrete Form (ICF) wall construction for the exterior, corridor and demising and shaft walls, metal stud walls for unit partitions and precast hollow core plank for the floors and roof framing or composite concrete floor deck. The following are the results of the cost estimate:

Wood Frame Construction Cost	ICF & Precast Floor Plank Construction Cost	ICF & Composite Concrete Floor Deck Construction Cost
$8,725,027.58 **($211.52 / sf)**	**$8,182,625.87** **($198.37 / sf)**	**$7,797,783.90** **($189.04 / sf)**

Please note the two (2) Concrete estimates INLCUDE a 4% architectural re-design allowance in their estimated costs. The detailed cost estimates are provided in the Appendices (1. Wood Frame, 2. ICF and Precast Concrete, and 3. ICF and Composite Concrete Floor Deck).

Cost Summary

Wood Framing vs. ICF & Precast Plank vs. ICF & Composite Concrete Floor Deck

ICF (Insulated Concrete Forms) and Precast Plank Flooring offers a **$542,401.71** savings or a **6.6%** cost reduction over the use of a wood-framed structure. ICF and Composite Concrete Floor Decking offers an even greater savings of **$927,243.68** or a **10.6%** cost reduction over Wood. The benefits of using ICF are not limited to a substantially reduced upfront first cost only. Some of the other realized benefits are as follows:

- Expedited construction schedules (**10%** to **15%** over other structural systems)
- Superior energy efficiency will allow the building to save as much as **15%** to **25%** on the cost of HVAC equipment due to the reduction in the heating/ cooling loads, resulting in an ROI evidenced by monthly utility costs being reduced as much as **30% plus**
- Increase sound attenuation, improving the occupants experience (STC rating of **55+**)
- Increased owner income (see Section "**2. Owner Income Estimate**")
- Builder's Risk and Owner Liability Insurance can be reduced by as much as **35%** to **50%** by utilizing ICF's storm-resistant, resilient exterior building shell

2. Operating Income Estimate

Operating income for the concrete building is **13.9%** higher because of savings for energy costs, insurance, and reduced vacancy because of reduced noise, increased thermal comfort, and lower rent plus utility costs. The highest net operating income is for the concrete building affording the owner the opportunity to charge typical room rental rates while incurring minimal utility costs.

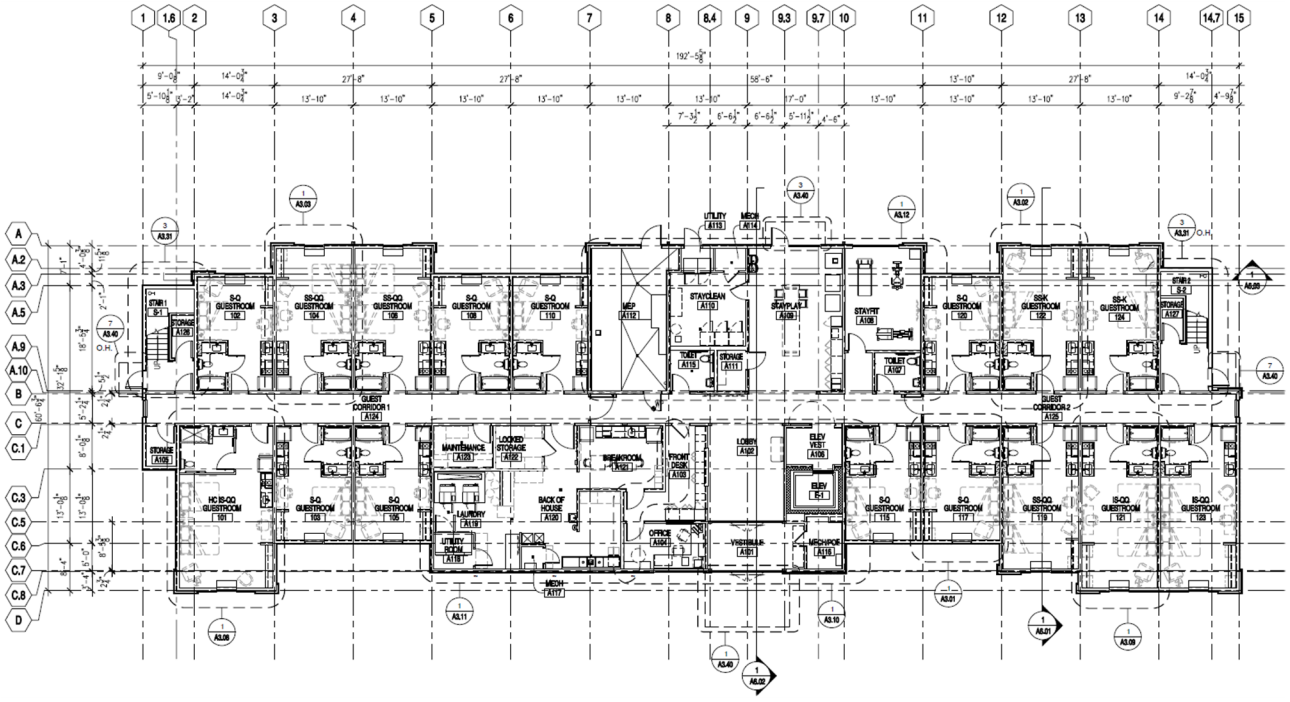
Estimated Operating Income and Expenses

Total Number of Rooms	**88**	
Estimated Energy Savings (%)	**25%**	(Estimated)
Property Insurance Savings (%)	**37%**	(From NRMCA Insurance Study)
Increased Occupancy (%)	**5%**	(From reduce noise, increased comfort)

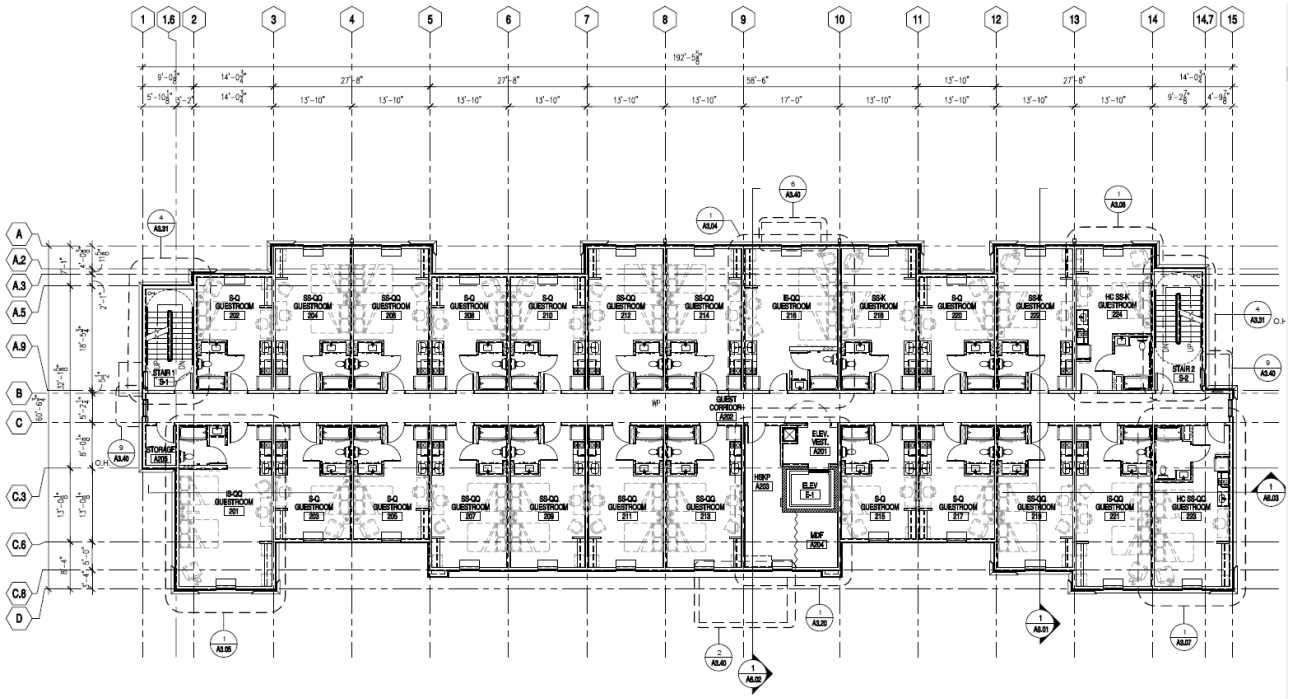
Source: **2019 CBRE Benchmark "Regional Revenue Per Room" Survey** (pre-pandemic)

		Wood Framed		ICF/Concrete
Revenues (PROJECTED)				
Rooms (Pre-Pandemic)	$	4,207,368	**$**	**4,417,736**
Food & Beverage (Site Specific)	$	-	$	-
Other Operating Departments	$	156,200	$	156,200
Miscellaneous Income	$	90,992	$	90,992
Total Operating Revenue	**$**	**4,454,560**	**$**	**4,664,928**
Operating Expenses				
Rooms	$	1,004,960	$	1,004,960
Food & Beverage (Site Specific)	$	-	$	-
Other Operated Departments	$	82,280	$	82,280
Administrative and General	$	326,128	$	326,128
IT Systems	$	47,784	$	47,784
Sales and Marketing	$	544,632	$	544,632
Operations and Maintenance	$	166,320	$	166,320
Utility Costs	$	126,368	**$**	**94,776**
Management Fee	$	149,072	$	149,072
Rent	$	159,016	$	159,016
Property Taxes	$	143,088	$	143,088
Insurance	$	52,008	**$**	**32,765**
Other	$	46,376	$	46,376
Total Operating Expenses	**$**	**2,848,032**	**$**	**2,797,197**
Net Operating Income	**$**	**1,606,528**	**$**	**1,867,731**

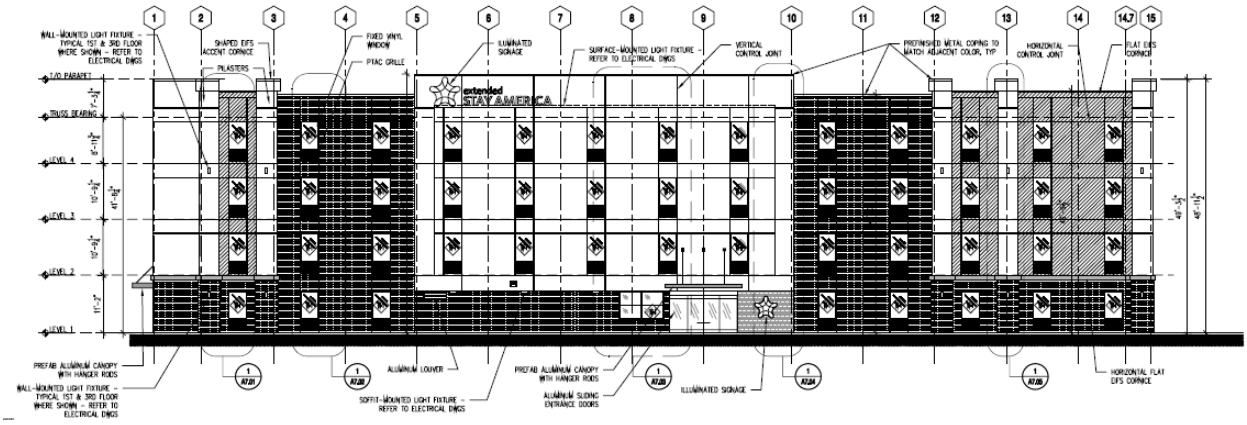
3. Assumed Project Details

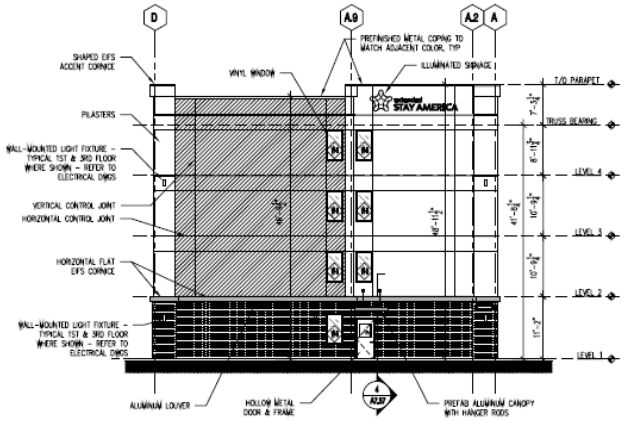


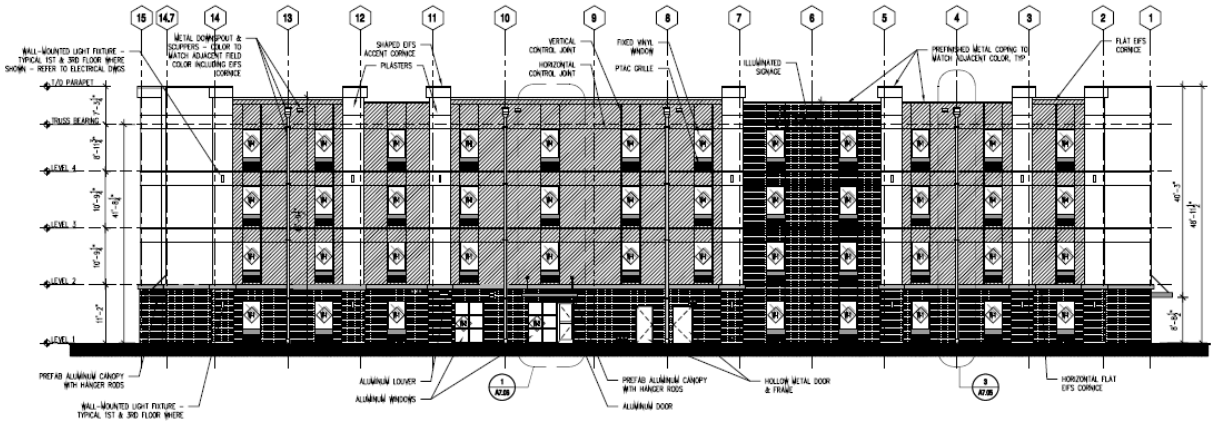
Main Level Floor Plan

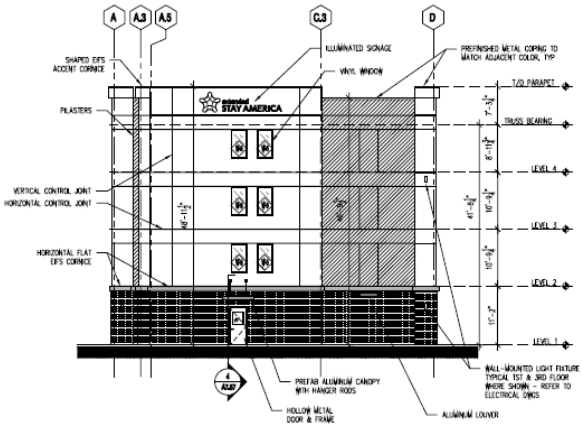


Upper Levels Floor Plan (Typical of 3)



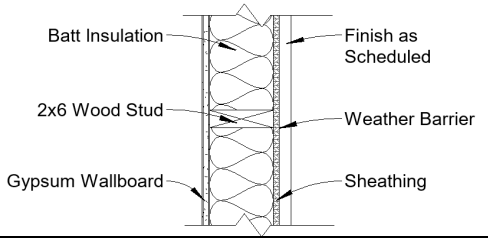
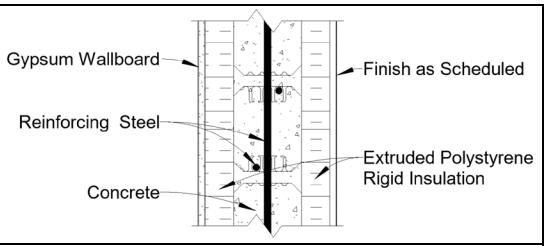






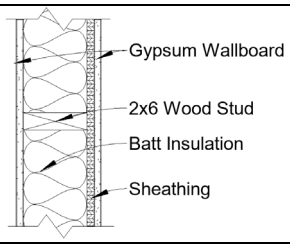
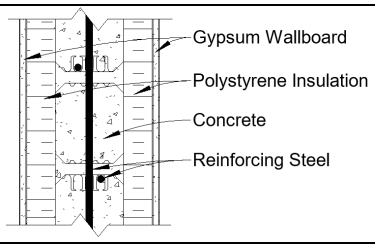
Exterior Elevations

Exterior Wall

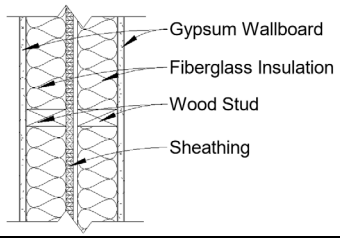
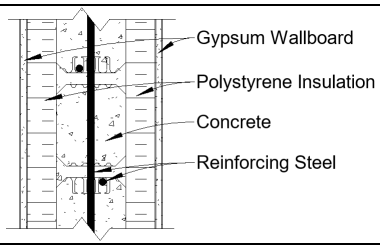
		
	2”x6” Wood Stud	**6” ICF**
R-Value*	**19.1**	**24+**

*Exterior finish not included

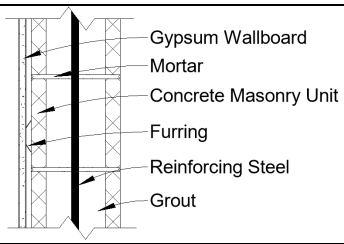
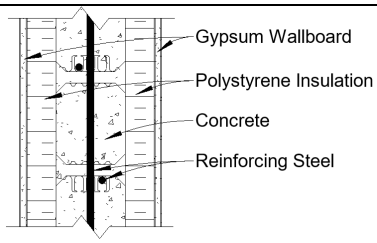
Corridor Wall

		
	2”x6” Wood Stud	**6” ICF**

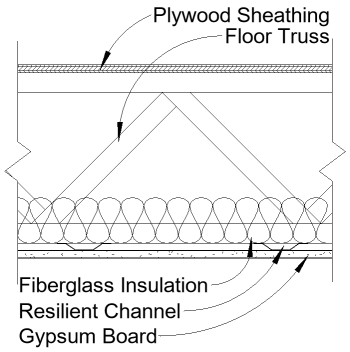
Demising Wall

		
	Two 2”x4” Wood Studs	**6” ICF**

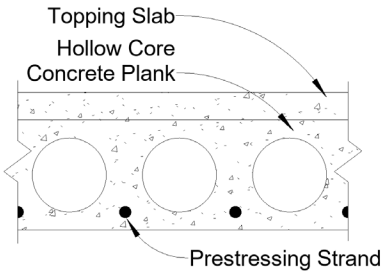
Shaft Wall

		
	8” CMU	**6” ICF**

Floors (Wood vs. Precast Plank w/Topping Slab)

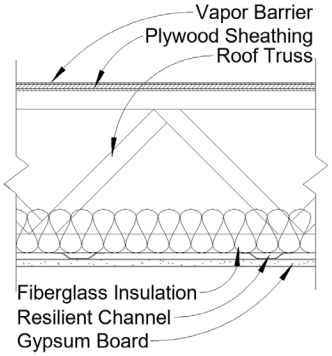


Open Web Wood Joist

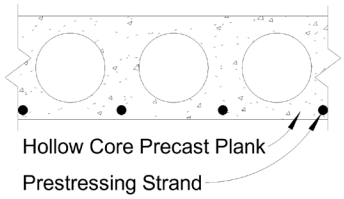


Precast Hollow Core w/Topping Slab

Roof (Wood vs. Precast Plank w/o Topping Slab)

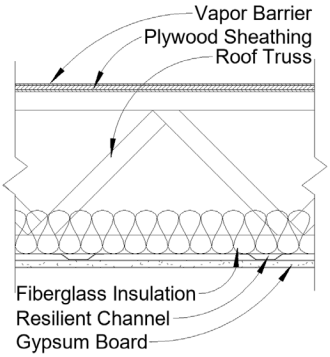


Open Web Wood Joist

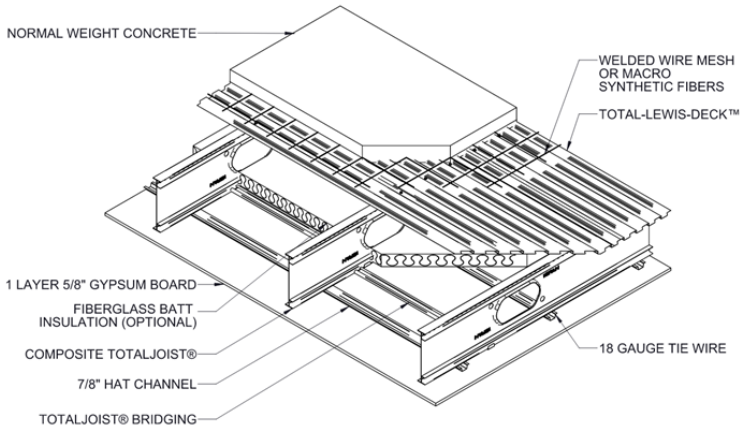


Precast Hollow Core (Roof)

Floors & Roof (Wood vs. Composite Concrete Flooring System)



Open Web Wood Joist



Composite Concrete Flooring System

4. Case Studies

The following are just a few examples of ICF hotels and other multi-family projects. For more examples visit www.ConcreteTracker.org.

The Microtel by Wyndham, Gambrills, Maryland

Image courtesy of Chaney Enterprises

The Microtel by Wyndham located in Gambrills, MD is an energy efficient hotel built with Insulated Concrete Form (ICF) construction. The hotel boasts five stories of usable space and 79 guest rooms. The non-combustible construction consists of ICF walls for the exterior, corridor, demising and fire walls, and precast hollow core plank for the floors and roof framing. ICFs are insulated foam blocks that lock into place and are then filled with reinforced concrete. They provide protection against adverse weather and termite damage, are easy to install and maintain, and offer great value for money. The advantages of building the Microtel with ICF construction far outweigh the disadvantages, especially when considering the alternative of traditional wood building methods.

Holiday Inn Express, Louisville, Kentucky

Image courtesy of ICF Builder Magazine

This eight-story Holiday Inn Express was built with ICFs in the heavily populated Museum Row district in downtown Louisville. Standing about 100 feet tall, it's the tallest building in the area. ICFs were selected in part because the extremely tight site meant construction materials had to be lifted from the adjacent parking garage since there were no staging areas outside the building footprint. Although Dunn Hospitality has built other hotels, this was their first ICF project. After touring another Holiday Inn project being built with ICF across the river in Ohio, they were convinced. ICFs cut three months off the already accelerated schedule. With conventional construction techniques, a typical eight-story, 145-room hotel such as this would take 14-16 months to construct but this hotel took only 10 months allowing the hotel to open just in time for the Kentucky Derby thanks to ICF construction.

Candlewood Suites, Omaha, Nebraska

Image courtesy of Fox Blocks

This four-story, 82-suite hotel is built entirely of ICF exterior and corridor walls. The system was selected to reduce noise from nearby Eppley Airfield in Omaha. The project, completed in 2008, is one of many hotels switching to ICFs for superior noise abatement along with superior energy efficiency, competitive construction cost and reduced construction schedule. ICF construction can help contain construction costs because of the inherent efficiencies of the installed assembly that serves nine functions including concrete form, thermal barrier, air barrier, moisture barrier, fire barrier, sound barrier, substrate for running utilities, substrate for attaching finish materials and reinforced concrete structure. In conventional construction, many of these elements are provided by several different trades, usually at significant added cost and time. As a result of using ICFs, building owners can put their buildings into service sooner, cutting short financing costs and initiating a quicker revenue flow.

Comfort Inn, Tifton, Georgia

Image courtesy of IntegraSpec

Dubbed the “best built hotel in our company” by Comfort Inn, the chain’s Tifton location is one durable hotel. Faced with an incredibly tight, four month building timeline, and a challenging budget, this hotel is a fantastic example of how ICFs can be used to save time and money without sacrificing durability by using stick frame. Thanks to its ICF construction, guests are kept safe and can enjoy a stay uninterrupted by traffic noise from the nearby interstate. The cost to build the hotel was $78 per square foot, like stick construction. Thanks to the energy efficiency benefits of ICFs, the hotel’s owners will save even more money over the building’s lifecycle.

Apartments and Condos

Beach Green North, Rockaway, New York

Image courtesy of The Bluestone Organization

This 101-unit, 94,000 square-foot apartment building is built in an area devastated by Hurricane Sandy in 2012. The Bluestone Organization selected ICFs for exterior, corridor and demising walls and precast hollow-core floors for disaster resilience and energy efficiency. The building is so energy efficient it is certified by the Passive House institute. ICFs create a solid concrete wall with continuous insulation, resulting in a comfortable and airtight structure that lowers energy bills. The reinforced concrete system results in a structure that's strong, durable and can stand up to fire, floods and wind. This developer builds exclusively with concrete.

Walker's Landing, Milwaukee, Wisconsin

Image courtesy of Bedford Development

Bedford Development chose ICF walls and precast hollow-core floors for thermal efficiency, fire rating and speed of construction. Walker's Landing has four floors of residential over two floors of parking. The project is located on an infill urban site requiring fire rated exterior walls. The ICF provides more than enough fire rating at a significant cost savings over wood frame. The ICFs are so energy efficient that some tenants have never turned their heat on all winter. The building also has garage heaters that have never been turned on. Bedford Developments used the vertical TF Forming Systems ICF resulting in minimal waste on the job site.

Central Avenue Villas, Oklahoma City, Oklahoma

Image courtesy of EPS Industry Alliance

The Villas were built with ICF exterior walls and precast hollow-core plank floors. In addition, the elevator shafts, stairwell walls and corridor walls were designed with ICFs to meet stringent fire code standards in addition to providing superior sound mitigation. The ICF portion of each level was installed in ten working days allowing the entire structural shell, floors and walls to be completed in only six weeks. ICF construction proved to be a cost-effective method to build a fire rated wall assembly directly abutting an existing structure. ICFs were used to support heavy loads on narrow columns between windows and beams in between floors. The developer promotes not only the ICFs' energy efficiency but also protection from tornadoes and superior noise reduction. The Central Avenue villas lie between I-235 and I-40 in Oklahoma City, yet traffic noise is nonexistent on the interior.

The Ricchi, San Antonio, Texas

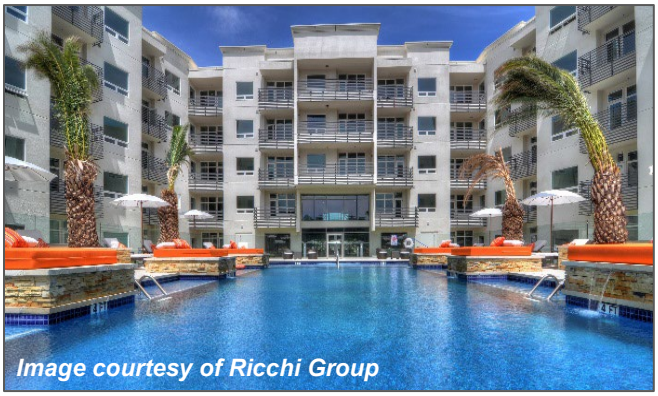


Image courtesy of Ricchi Group

The Ricchi condominiums in San Antonio are a contemporary, mid-rise building consisting of 87 luxury condominiums. This exclusive development was the first of its kind to be built in the area. The developers wanted to provide a first-class, secure and quiet building and chose ICF as part of the plan to achieve their goal. Noise reduction was a major consideration for this project. The Ricchi is located directly below the flight path for airliners approaching San Antonio's international airport and is adjacent to a US Army training camp. The sound attenuation offered by ICFs provided a solution to those concerns while creating significant energy savings. The U-shaped, luxury condo utilized more than quarter million square feet of ICFs. The higher insulation provided by the ICF walls reduced HVAC tonnage by 20 percent, resulting in significant energy savings.

Lane 1919 Apartments, Portland, Oregon

Image courtesy of Oasis Architecture

A focus on quality, reduce life-cycle costs, and the creation of value for the next 80 years drove the Lane family along with the rest of their investment and design team to create a mixed used project that paid tribute to the historic significance of the neighborhood while combining modern innovative design and construction methods. The project team's goals were not only to create a viable income-producing property for the Lane family, but also to balance energy efficiency and extended life-cycle equipment and materials. The Lane 1919 mixed-use tower is built from highly efficient, ICF walls that provide greater thermal mass, high R-value and reduced air infiltration offering the building owner significantly reduced energy bills.

Grand Caribbean, Orange Beach, Alabama


Image courtesy of IntegraSpec

This 160,000-square-foot beachfront condominium project was built using ICF bearing walls throughout and concrete on steel joists for the floors. The developer chose ICFs because the building is in a hurricane area and needed to resist high winds, flying debris and water infiltration. They also used ICFs to kill sound from one unit to the next. The one thing the unit owners all talk about is how quiet the units are. A third reason is energy efficiency. The owners are happy that their power bills are so low. The Grand Caribbean captures the turn-of-the century Victorian look that is still very appealing in the housing market. The project was so impressive that the units were sold out before construction even started.

5. Noise Reduction

Concrete walls and floors have long been the material of choice for reducing sound transmission (which is key to a better occupant experience) in the multifamily sector. ICFs are often used for apartment and hotel projects due to their ability to isolate and dissipate noise. Controlling noise transmission in residential buildings is also important both for reducing interior noise between units and from the outside sources. Most multifamily buildings, whether they are apartment buildings or hotels, are generally located in urban centers where noise generated by automobile traffic can affect the occupant's quality of life. No one desires to live in building where you can hear your neighbors.

So, what can owners of multifamily buildings do to meet the sound isolation expectations of their residents? Several techniques can be used to address these issues as it relates to construction methods and applications. For reference, every sound isolation problem has three elements:

- **source** – noise generator (loud stereo or instrument, voices, solid surface being struck)
- **path** – channel for sound-wave travel or a solid connection from source to receiver
- **receiver** – one hearing the source (occupant being disturbed – the residents)

To gain a better understanding of the impact normal everyday sounds have, the **STC** (Sound Transmission Class) and the **IIC** (Impact Isolation Class) methods of rating sound intrusion was specifically developed. See the following table to understand and gauge the effects of typical sounds (and their associated STC ratings) in residential environments:

Typical Sounds STC Ratings

STC Rating	Privacy Afforded
25	Normal speech easily understood
30	Normal speech heard but not understood
35	Loud speech heard and somewhat understood
40	Loud speech heard but not understood
45	Loud speech barely heard
50	Shouting barely heard
55	Shouting not heard

Sources:

"*Quieting: A Practical Guide to Noise Control*", NBS Handbook 119, Nat. Bureau of Standards, U.S. Dept. of Comm., Washington, DC,

In construction, there are three primary methods for improving sound isolation:

1. **Block** - seal all gaps, cracks, and leaks. This is the easiest and most effective means to isolate sound. Sound will always find the weakest path—other attempts to improve sound isolation will be ineffectual if the gaps are not sealed first.
2. **Build Up** - increase the mass of the construction. This makes it more difficult for the airborne sound to cause the partition to vibrate from one surface to the opposite side.
3. **Disconnect** - introduce decoupling (breaks) into the construction. This allows one side/surface to absorb the vibrations without transferring it (i.e., block the path).

Given these methods of how sound infiltration is measured, there is data that quantifies attenuation within specific wall and floor assemblies. Designing to the minimum standard of the building code will not suffice for proper sound attenuation in multi-family / hospitality construction (typically the code accepts STC 45 or better). It's necessary to evaluate and measure sound transmission reduction in all types of wall / floor / ceiling assemblies, and all sources of environmental noise or vibration to achieve adequate sound attenuation. The following are examples of typical STC ratings for walls assemblies. The IIC (Impact) ratings are not typically referenced for walls because the rating is a "strike" or contact measurement, therefore only STC is considered and typically referenced:

WALL ASSEMBLY STC PERFORMANCE GUIDE

STC Rating	Assembly Build	Performance
32	Single layer of 1/2" drywall on each side, wood studs, no insulation (typical interior wall)	**Poor**
38	Single layer of 1/2" drywall on each side, on a staggered wood stud wall	**Poor**
44	Double layer of 1/2" drywall on each side, wood studs, sound batt insulation in the wall	**Fair**
50	Single 5/8" drywall on one side, double 5/8" drywall on the opposite side and sealant on other side of wood studs	**Fair**
54	Double-layer of 1/2" drywall on each side, on a staggered wood stud wall, double-layer sound batt insulation in the wall	**Good**
57	6" ICF Wall - (6" thick concrete core with two 2-1/2" EPS foam each side with 6" monolithic concrete core) and a single layer of 1/2" drywall each side	**Good**
60	Double 5/8" drywall on one side (single layer on opposite side) of a metal stud wall with double layer sound batt insulation and sealant top and bottom of wall (one side only)	**Better**
62	Double 5/8" drywall on one side (single layer on opposite side) of a metal stud wall with sound batt insulation and sealant top and bottom of wall, both sides	**Better**
64	Double layer of 1/2" drywall on each side, on double wood / metal stud walls (spaced 1" apart), double sound batt insulation and sealant top and bottom of wall, both sides	**Excellent**
67	6" ICF Wall - (6" thick concrete core with two 2-1/2" EPS foam each side with 6" monolithic concrete core) and a single layer of 5/8" drywall on resilient channel each side	**Excellent**

Sources:

"Wall Assembly STC Performance" - National Research Council - The National Academies of Sciences, Engineering, & Medicine, NA
"Insulating Concrete Forms for Multifamily Residential Construction" - Build With Strength Coalition - NRMCA, June 1, 2019
"ICFMA Design Guide for Multi-Storey Buildings" - Insulating Concrete Forms Manufacturers Association, ICF-MA.org, 2017

The source of most sound infiltration (between units) in multifamily or hospitality construction does not come through the walls but instead from overhead and below. The ability to control sound and vibration through the floor structure is key. The following table is a comparison of the available floor construction assemblies and their typical average rating(s) for sound:

FLOOR ASSEMBLIES SOUND PERFORMANCE GUIDE: **STC** (Sound Transmission Class) and **IIC** (Impact Isolation Class)

FLOOR ASSEMBLIES with 5/8" GYPSUM BOARD CEILING ONLY (No Floor Finishes Applied)	STC (Air-Borne Sound) (higher number = better performance)	IIC (Impact Sound) (higher number = better performance)
Basic wood floor (I-joist, solid-sawn, or truss, ¾" sheathing, 5/8" gypsum board ceiling)	**36**	**33**
Basic Wood Floor (with 1 ½" concrete topping)	**44**	**34**
8" Hollow Core Planks (No Gypsum Board Ceiling Below)	**50**	**28**
Composite Floor System with 4" Concrete Floor Slab (with 5/8" Gypsum Board Ceiling on Resilient Channel)	**56**	**36**
8" Hollow Core Planks (with 1 ½" concrete topping)	**58**	**29**
8" Hollow Core Planks (with 1 ½" concrete topping and (with 5/8" Gypsum Board Ceiling on Drywall Grid Suspended from Resilient / Isolation Ceiling Hangers & Sound Batt Insulation)	**63**	**34**
Composite Floor System with 4" Concrete Floor Slab (with 5/8" Gypsum Board Ceiling on Drywall Grid suspended from Resilient / Isolation Ceiling Hangers & Sound Batt Insulation)	**67**	**36**
Insulated Concrete Decking (13" Foam Form, 3" Cast-In-Place Concrete Floor Slab w/Integrated Structural Load-bearing Joist, with 5/8" Gypsum Board Ceiling on Resilient Clips)	**67**	**61**

Sources:

Structural Building Components Association - "Sound Transmission in Wood Floor and Roof Trusses", Acoustical Properties of Hollow Core Floor Slabs, 8/29/16
Marsh Day Acoustics - Speedfloor Composite Floor Decking "Estimated airborne sound insualtion performance of Speedfloor systems", March 2013
LiteForm Technologies "STC (Sound Transmission Class) and IIC (Impact Isolation Class) Field Tests of Typical Lite-Deck Floors - Sound Tests 07", May 21, 2007
Structural Building Components Association (SBCA) "Sound Transmission in Wood Floor and Roof Trusses", 08/29/16 Mid South Prestressed - Acoustical Properties of Hollow Core Floor Slabs

It is also widely known that floor finishes can assist in the overall sound rating (specifically IIC or impact) rating of floor/ceiling assemblies as well. The following finishes may contribute positively to increasing the control of sound transmission and the IIC rating of some floor assemblies:

- Pile Carpet Tiles with Rubber backing + 22 dB
- Pile Carpet on ½" Underlayment Pad + 32 dB
- Cushioned Vinyl Tile or LVT Plank + 16 dB
- Wood / Laminate / Engineered Flooring on Foam Underlayment + 15 dB
- Ceramic/Porcelain Tile on Cork/Rubber Underlayment + 15 dB

Concrete offers excellent noise control in two ways. First, it effectively blocks airborne sound transmission over a wide range of frequencies. Second, concrete effectively absorbs noise, thereby diminishing noise intensity. Because of these attributes, ICF walls and floors, concrete or precast planks, and composite concrete floor systems have been used successfully in multifamily, hospitality and theater applications to diminish sound infiltration and provide a much quieter environmental setting that fosters community while reducing property vacancy.

6. Benefits of ICF Construction

Competitive Construction Cost

In general, insulating concrete form (ICF) construction is cost competitive with wood frame construction. In most cases, ICF walls replace the wood stud bearing walls for a typical multi-family residential building such as an apartment, hotel, dormitory or long-term care facility. The key reasons for cost competitiveness is that ICF walls are less complicated to build than wood frame walls and reduce the number of trades involved in building a wall. In addition, most wood details required to meet building code requirements for energy efficiency, fire and noise have increased over the last two decades thus making ICF wall construction more cost competitive. See Section 1 for details.

Increased Operating Income

Owners of concrete buildings often experience increased operating income over wood frame buildings. The increase mainly comes from savings for energy costs, insurance and reduced losses to vacancy because of reduced noise, increased thermal comfort and lower rent plus utility costs. Concrete buildings have higher net operating income for both the individual metered and the master metered apartment building. However, the highest net operating income is for concrete building that are master metered allowing the owner to charge typical rental rates then add a utility rate that is equal to or higher than the actual utility rate charged by the utility company. See Section 2 for details.

Reduced Insurance Costs

Insurance costs for both builder's risk insurance (during construction) and commercial property insurance (during occupancy) are lower for concrete construction compared to wood frame construction according to a study conducted by NRMCA. For builder's risk insurance, the greatest difference found in the quoted cost of insurance at any location was 72% less for the concrete building and the smallest was 22% less. For commercial property insurance, the greatest and smallest differences found were 65% and 14% less, respectively.

According to the study, some agents volunteered their views on the future of insurance rates and practices for different building materials. They suggested that the gap between rates for wood frame and concrete is likely to grow in the future and that a growing number of insurers are declining to serve as sole insurer for wood-frame apartment buildings. Additionally, insurers of such buildings are increasingly requiring that the insured take extra measures to protect against loss and especially fire loss.

Speed of Construction

ICF systems result in construction that is faster, easier and less labor intensive than other construction methods such as wood or steel framing. ICFs are lightweight, durable and offer a system that requires less skilled labor. The system combines the reinforced concrete structural system along with the thermal, air and moisture barrier in one step which reduces the number of trades required on site. Construction can continue all year long since the forms provide an ideal

curing condition for concrete during the hottest and coldest weather. This all results in cutting several weeks and sometimes months off the construction schedule thus saving on costly construction loans and starting the revenue stream earlier.

Ease of Construction

Because the forms stay in place after concrete is poured there is no need for labor intensive wood, aluminum and steel formwork that requires large cranes and other expensive hauling equipment. ICFs are user friendly which means that construction crews new to the system can learn the method quickly. Many crews are familiar with the running bond stacking method used in masonry construction, but instead of stacking small, heavy blocks with wet mortar, they are installing large blocks made with polystyrene, meaning crews can install more wall area per day. The following table shows the construction steps needed for wood frame construction compared to ICF construction.

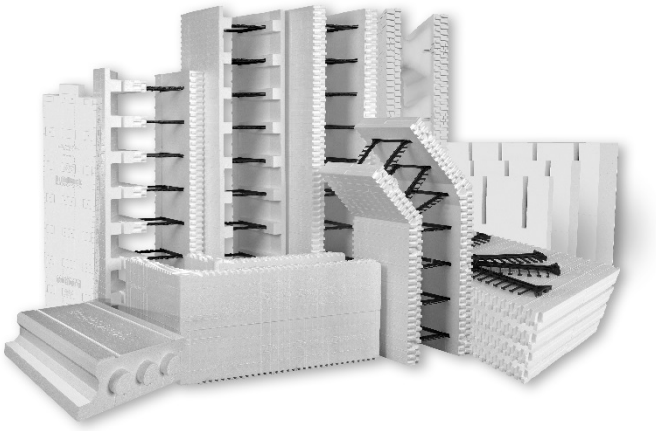


Image courtesy of BuildBlock

Wood Frame Construction	ICF Wall Construction
1. Install stud wall 2. Brace wall 3. Install fire stops 4. Install sheathing 5. Install electrical and plumbing 6. Install insulation 7. Install continuous insulation 8. Install house wrap 9. Install finishes	1. Install forms 2. Install reinforcement 3. Brace walls 4. Pour concrete 5. Install electrical and plumbing 6. Install finishes

Lower Floor-to-Floor Heights

One of the major areas where concrete systems can save money over wood frame is in reduced floor-to-floor heights. A typical wood floor truss system is often 24-27 inches deep depending on the soundproofing details, whereas a typical concrete floor system is only 10-12 inches deep thus reducing the floor-to-floor height by 12 inches or more. This might not seem like a significant savings; however, it adds up over 5 or 6 stories. Reduced exterior wall finishes, reduced electrical and plumbing runs among other reductions can result in significant cost savings for concrete over wood frame.

Reduced Ceiling Finish

Concrete floor systems such as precast hollow core plank have a smooth finish that does not require additional drywall or plaster. Often, the only ceiling finish required is paint. At the most, one can provide a smooth plaster coat to the underside of the slab if desired, but generally that is not necessary. This type of construction is common in hotels and dormitories but can be easily adapted for apartment and condominium construction by providing soffits in the service areas such as kitchen and bathrooms. In fact, soffits often add interest and aesthetic appeal to a typical flat ceiling design.

Noise Reduction

Concrete walls and floors have long been used as the material of choice for reducing sound transmission, which is key to a better occupant experience for multi-family residential construction. ICFs are often used for their ability to isolate and dissipate noise. Noise transmission in residential buildings is also important both to reduce noise between units and from the outside. Most multifamily buildings, whether they are apartment buildings or hotels, are generally located in urban centers where car and truck traffic can affect occupants' quality of life. And no one wants to live in an apartment building where you can hear the neighbors or stay in a hotel where you can't sleep because of traffic noise. The fact that ICFs can nearly eliminate sound transmission at virtually no additional cost makes them very attractive for any project in which peace and quiet is a selling point.

The concrete core of ICF offers excellent noise control in two ways. First, it effectively blocks airborne sound transmission over a wide range of frequencies. Second, concrete effectively absorbs noise, thereby diminishing noise intensity. Because of these attributes, ICF walls and floors have been used successfully in multifamily and hospitality applications. The International Building Code has requirements to regulate sound transmission through interior partitions separating adjacent dwelling units and separating dwelling units from adjacent public areas. Six-inch ICF walls easily achieve STC 55 (Sound Transmission Classification) rating. Higher STC ratings up to STC 70 can be achieved with additional gypsum wallboard or special isolation channels. For concrete floors, most meet STC 50 or higher and IIC (Impact Insulation Class) of 50 or higher depending on the floor and ceiling finish as required by the IBC.

Energy Efficiency and Thermal Comfort

ICF walls are considered by the IECC and ASHRAE 90.1 as mass walls with continuous insulation. Typical whole wall ICF assemblies have an R-value between R-24 and R-26 depending on the exterior and interior finish materials compared to R-11 and R-19 for 2x4 and 2x6 wood frame. Thermal resistance (R-value) does not consider the effects of thermal mass, and by itself does not fully describe the beneficial properties of ICFs. The damping and lag effect of thermal mass means fewer spikes in heating and cooling requirements since the mass buffers indoor temperature fluctuations, contributing to occupant comfort. Thermal mass shifts energy demand

to off-peak time periods when utility rates are lower, reducing costs further. ICF walls can exceed the requirements for all climate zones for both residential and commercial thermal envelopes above and below grade because of the combination of extreme R-value and thermal mass.

Achieving a high-performance building envelope also means minimizing air leakage and ICF walls are tighter than wood-frame or light gauge steel walls. In tests, they averaged about half as much air infiltration as wood frame. In many cases the air infiltration rates are as low as 0.5 air changes per hour. Thermal bridging is also eliminated with ICF walls when compared to wood and light gauge steel. Since energy consumption of ICF buildings are lower, the HVAC systems can be smaller and more efficient, adding to energy savings. The result is energy savings ranging from 20 percent to as much as 50 percent depending on other energy efficiency strategies employed for the building.

Fire Resistance

The U.S. Fire Administration reports that fire kills more Americans than all other natural disasters combined. In 2015, there were 1,345,500 fires reported in the United States. According to the National Fire Protection Agency, these fires caused 3,280 civilian deaths, 15,700 civilian injuries, and $14.3 billion in property damage. Of all the construction materials used today, concrete is the most fire resistant. This gives the noncombustible concrete structure important safety advantages over traditional combustible wood frame structures.

Unlike wood, concrete cannot burn; and unlike steel, it won't soften or bend. Concrete will only break down at temperatures of thousands of degrees Fahrenheit, which is far hotter than the temperature of a typical structure fire. Fire safety is important for any building occupancy, but it's especially critical for residential type construction where people sleep. Concrete has long been recognized as the most fire resistant of all building materials and there are decades of testing available to demonstrate this. However, as with all building assemblies, they must be tested using standard fire tests to demonstrate their fire-resistant capabilities.

Most ICF manufacturers have tested their products in accordance with standard fire testing protocol including ANSI/UL 263-13th Edition and ASTM E119-07. In general, 4-inch ICF walls achieve a 2-hour fire rating, 6-inch ICF walls achieve a 3- or 4-hour fire rating and 8-inch and thicker ICF walls exceed a 4-hour fire rating. Generally, the assemblies tested include reinforced concrete with a minimum compressive strength of 2,900 psi and 1/2-inch gypsum wall board on each side.

In addition to fire resistance rating of wall assemblies, it is important to understand the behavior of the EPS under fire conditions. The EPS used for ICFs is manufactured with flame retardants that render the EPS insulation completely unable to support a flame without an outside flame source; it is approximately five times better than wood at stopping flame spread from materials burning in close proximity. That means an extra margin of safety for occupants and first responders. EPS used for ICFs is strictly required to have a flame spread index of less than 25 and smoke developed rating of less than 450 when tested in accordance with ASTM E84 & ANSI/UL 723. ICF companies that maintain national evaluation reports from ICC-ES or other accredited testing agencies have all conducted a long list of materials tests in order to comply with national safety standards.

Disaster Resilience

The heart of ICF construction is reinforced concrete. Reinforced concrete walls and floors have long been the building material of choice for resisting structural loading from wind, earthquakes, flooding and fire. There are many examples of concrete buildings surviving natural disasters while surrounding buildings built with less durable materials simply don't have the strength and durability to resist the loading. Concrete walls and floors are designed using traditional requirements of the ACI 318 Building Code Requirements for Structural Concrete. The same analysis and design techniques used on traditionally formed concrete buildings are used on ICF buildings. What makes ICF structures even stronger and more durable is the fact that the walls and floors are tied together with overlapping reinforcing steel creating a solid monolithic structure.

These types of structures are extremely resistant to high loading and provide significant redundancy which avoids catastrophic failure. The solid walls act as shear walls to resist wind and earthquake loading. They also provide protection from flying debris from hurricanes and tornadoes. Because concrete and EPS are water resistant, even when a building is subject to flooding, the structure survives. This property protection is vital for communities to withstand and recover from disruptive events.

7. ICF Wall Systems

Often, insulating concrete forms (ICFs) are used for the exterior, corridor, demising and fire walls in bearing wall type buildings. ICFs combine two well-established building products, reinforced concrete and expanded polystyrene (EPS) insulation. The ICF form units are stacked in the shape of the wall, reinforcing steel is added into the form cavity and then concrete is placed into the form. The result is a reinforced concrete wall with a layer of insulation on each side. The forms remain in place after the concrete is cured to provide thermal insulation. The combination of reinforced concrete and insulation provides an ideal load bearing wall, thermal and moisture envelope, fire barrier and sound barrier.

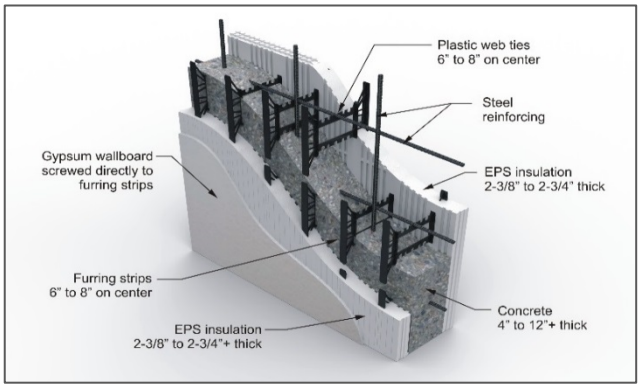


Image courtesy of Logix

ICFs are cost competitive and can be used for all types of commercial and residential construction – from single family to low- to mid-rise multifamily to high rise office and residential. A building owner gets a building that is more disaster resilient and energy efficient at or nearly the same cost. Fire safety is a key element of multifamily construction since occupants sleep in these buildings and are often challenged to evacuate during a fire. Concrete walls and floors provide the fire resistance needed to not only allow occupants to evacuate, but contain the fire within a single unit, imposing less risk on fire fighters and property.

Image courtesy of Fox Blocks

Insulation

Expanded Polystyrene (EPS) insulation used for ICFs is governed by ASTM C 578, Type II closed cell foam with an R-value of 4 per inch. Polystyrene beads are first expanded with steam forming high density beads, which are injected into a mold to form the desired shape. Once removed from the molds and cured, EPS is a stable and durable material ideal for construction. No chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) or formaldehydes are used in the manufacturing process and there is no off-gassing. EPS is moisture resistant, non-absorbent and resistant to mold and rot. EPS contains a flame retardant and the smoke from burning is non-toxic. In addition, EPS is recyclable at its end of life.

Plastic Ties/Furring Strips

The plastic ties that hold the two wythes of the block together are generally made with polypropylene plastic, but it does depend on the manufacturer. They are designed to withstand the liquid concrete pressure during construction. Most manufacturers design their ties to secure horizontal and vertical reinforcing bars into notches in the ties to minimize the need to use tie wire. The most common spacing is 6 or 8 inches. The ties have no thermal bridging, they do not rot or rust over time, and all ties have furring strips embedded in the EPS for screw-on attachment of exterior or interior finishes.

Reinforcing Steel

Reinforcing steel used in ICF walls is the same used for any other type of concrete structure. Typically, smaller diameter bars are used such as #4, #5 or # 6, but thicker bars can be used for higher loading, concentrated loads and pilasters. In some cases, steel fibers have been used in place of horizontal steel in ICF walls, but most common applications use both horizontal and vertical steel reinforcement.

Concrete

Concrete is typically placed in ICF walls using a boom-type concrete pump, though line-pumps or even conveyor belt equipment can be used. Specified compressive strength used in ICF walls can be whatever is required to resist structural loading, but most common are a 3000 psi or 4000 psi concrete pump mix. The recommended maximum aggregate size should be ½-inch aggregate for 4- and 6-inch cavity forms and ¾-inch aggregate for 8-inch and larger cavity forms. The required concrete slump is 6 inches but could be up to 8 inches or more to accommodate pumping using high-range plasticizers and mid-range water reducing admixtures to achieve necessary flowability.

Image courtesy of Quad-Lock

Electrical, Plumbing and Finishes

As construction continues, electrical and plumbing lines can be embedded into the interior layer of foam by cutting channels with a hot-knife or other tool. Interior or exterior finishes can be applied directly to the surface by screwing into the plastic furring strips. Gypsum wall board on the interior, and stucco, brick or siding on the exterior are common finishes ideally suited to ICF construction but nearly any finish can be applied.

Construction Process

The construction process is simple which is why ICF construction is so cost effective and helps reduce construction time. When building multi-story buildings, the walls are generally erected and cast one story at a time. Structural floors are installed and finished before continuing with walls on the next level.

There are also examples of walls being placed several stories at a time and installing structural slabs later. Some contractors have panelized ICF walls off site to further reduce construction time. Others are beginning to use steel fibers in place of horizontal shrinkage and temperature reinforcement which can also significantly reduce construction time.

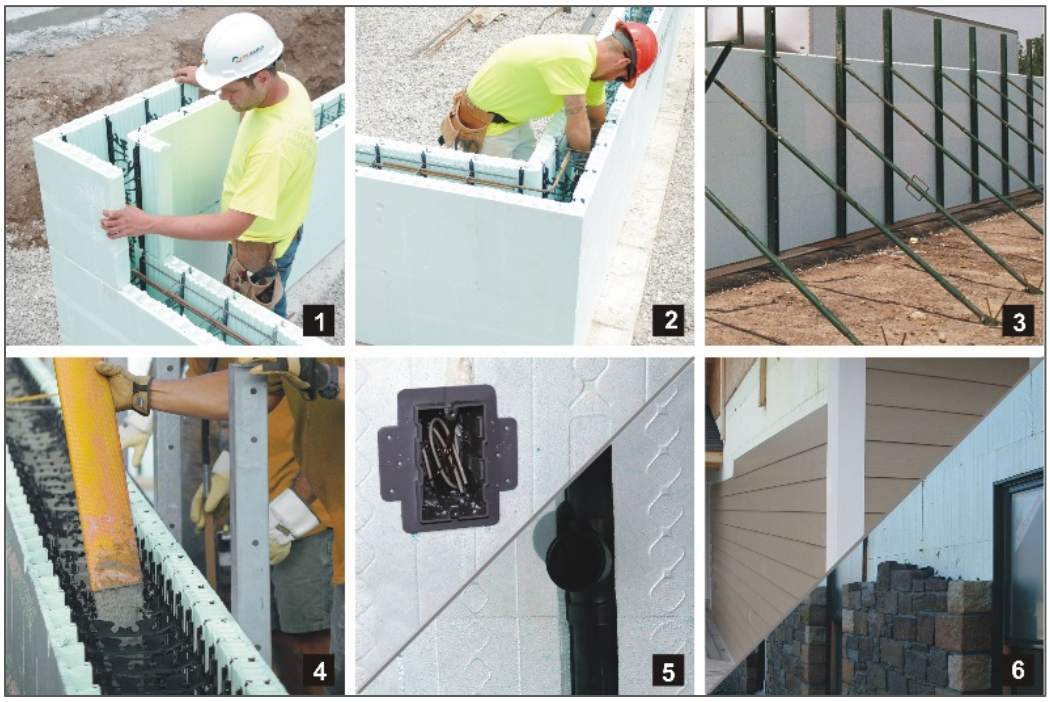


Image courtesy of Nudura

Once the foundation or structural floor is in place, the following process is followed:

- **Step 1:** ICFs are stacked in the shape of the wall and openings for windows and doors are formed using bucks made of treated wood or plastic
- **Step 2:** Then steel reinforcing (rebar) is placed into the forms vertically and horizontally, like a cast-in-place wall, and secured in place with ties
- **Step 3:** Bracing and scaffolding are installed to keep the wall straight, plumb and secure and to provide a working platform
- **Step 4:** Concrete is pumped or placed into the forms using a pump truck with a snorkel boom (preferred) or a line pump into the forms
- **Step 5:** Electrical and plumbing lines are installed into the EPS by cutting channels with a hot knife or other tool
- **Step 6:** Interior and interior finish is installed directly to the ICFs by screwing into the embedded plastic furring strips

8. Precast Concrete Floor System


Image courtesy of Amvic

There are several concrete floor and roof systems used in combination with ICF wall construction. Precast Hollow-Core Plank for the floor and roof system, one of the most popular systems for multifamily construction. Typically, ICF walls are installed one story at a time (including concrete) and then precast planks are placed on top of the walls, bearing directly on the concrete. Sometimes a concrete topping is placed on the plank or a thin leveling layer is used to even out the floor to accommodate any finish. For some buildings, the ceiling is simply painted or parged with plaster and painted to conceal the joints between planks. There are dozens of hollow-core plank manufacturers around the U.S. and Canada that can supply product for ICF projects, and several have developed special details specifically for ICF construction.

Strength & Durability

For the strength factor alone, concrete is the most economical and reliable of building materials. Built to last decades, precast concrete retains its strength whether it's above ground or below. Because it can be made in a facility well before it's needed, precast concrete can strengthen for weeks. Not only is precast concrete strong, but it's also very durable – which is not necessarily the same thing. Precast concrete infrastructure is designed to last up to 100 years, resisting damage from the elements and natural disasters. Precast concrete will also not catch fire, and it will prevent the spreading of fire from floor to floor. It is a fantastic material to have a building made from for this very reason. In the event of a fire, the precast concrete will not get so hot as to drip molten particles and light other materials on fire.

Environmental Control & Sustainability

Precast concrete is also one of the more environmentally stable and sustainable building materials on the market. Precast concrete is very dense and sturdy, making it a fantastic material choice for buildings where sound proofing is a top priority. Multi-family residential and student dormitories also benefit from precast as it limits noise transfer from floor to floor. Commercial buildings in large metropolitan areas also often use precast concrete for this very reason. It also is an excellent thermal mass sink for temperature control from floor to floor, promoting structural thermal lag that assist's in maintain the building's interior climate. Also, because of the controlled environment during precast concrete production, any wastewater or materials created can be saved and reused. Precast concrete remains incredibly strong for decades, is resistant to fires and floods, and repels pest intrusion. If anything in the construction business has "set it and forget it" properties, it's concrete. That's why some form of it has been used for hundreds of years.

9. Composite Concrete Floor System


Image courtesy of Speedfloor, USA

Composite Concrete Floor Systems are suspended concrete flooring systems that are very quick and easy to install and are a lightweight, cost-effective system that's ideal for multi-storied residential or commercial buildings and parking garages. Whether it's one story or fifteen, the design is very simple: take galvanized metal floor joists, add structural steel and concrete supports, then add the steel-reinforced ready mixed concrete and pour! At the heart of the system is a special roll formed, galvanized steel joist that offers all the benefits of an open-webbed truss system at a more competitive price. It needs no propping and is light enough to be manhandled into place - reducing or elimination the need for a crane while saving substantial time and expense.

Composite Concrete Floors are faster, lighter, and easier than traditional flat plate construction and can achieve savings of up to 25% due to its speed of installation. Other key benefits include:

- **Vibration Control:** Every flooring system is reviewed with a proprietary design method to ensure great feeling floors and reduce unnecessary movement even in seismic zones
- **High Acoustic Ratings:** Helps minimize the #1 reason for complaints of multi-family living – noise intrusion from floor to floor.
- **High Fire Ratings:** Made with non-combustible materials. Minimum 2-hour UL/ULC rating with only one layer of rated drywall attached to furring channels under the system
- **No Shoring Required:** Pre-cambered joists eliminate the need for shoring during concrete topping pour. Steel decking as stay-in-place formwork reduces the schedule by eliminating the need to place and tear down formwork.
- **Ease of Installation:** Pre-engineered components can be installed quickly and easily without the need for specialized trades

Most manufacturers provide a load vs. span calculator that is available to designers and specifiers. The cold-formed joists are manufactured from high strength, pre-galvanized steel. The concrete slab is designed to have a minimum compressive strength after 30 days. The system's acoustic performance meets or exceeds building code design criteria and is supported by independent reports (available on request). Full scale fire tests have established that the system can be fire rated and meets fire rating.


Image courtesy of iSPAN

10. Disclaimer

This report has been prepared solely for information purposes. It is intended solely for the use of professional personnel, competent to evaluate the significance and limitations of its content, and who will accept full responsibility for the application of the material it contains. The National Ready Mixed Concrete Association and any other organizations cooperating in the preparation of this report strive for accuracy but disclaim any and all responsibility for application of the stated principles or for the accuracy of the content or sources and shall not be liable for any loss or damage arising from reliance on or use of any content or principles contained in this report.

Appendix 1: Detailed Cost Analysis for Wood Frame Construction

Cost Estimate Report

Date: 04/28/2021

Prepared By:

Unit Detail Report by WBS

Unit Line Number	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Subtotal					
Subtotal					
General Contractor's Markup on Subs					
Subtotal					
General Conditions					
Subtotal					
General Contractor's Overhead and Profit					
Unit Cost Total					

Assembly Detail Report by WBS

Year 2021 Quarter 1

Assembly Number	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl.O&P
Category: 41_500 SF Reference Hotel - WOOD					
A10101102500	Strip footing, concrete, reinforced, load 5.1 KLF, soil bearing capacity 3 KSF, 12" deep x 24" wide	1,145.00	L.F.	$34.71	$39,742.95
A10102107100	Spread footings, 3000 PSI concrete, load 25K, soil bearing capacity 3 KSF, 3' - 0" square x 12" deep	10.00	Ea.	$153.97	$1,539.70
A10102107450	Spread footings, 3000 PSI concrete, load 125K, soil bearing capacity 3 KSF, 7' - 0" square x 17" deep	16.00	Ea.	$820.44	$13,127.04
A10301202240	Slab on grade, 4" thick, non industrial, reinforced	11,723.00	S.F.	$4.75	$55,684.25
A20101105760	Excavate and fill, 30,000 SF, 4' deep, sand, gravel, or common earth, off site storage	12,000.00	S.F.	$0.33	$3,960.00
A-FWL-CIP	Foundation wall, CIP, 1.5' wall height, direct chute, 10" thick	1,203.00	L.F.	$23.31	$23,061.51
A-FWL-CMU8	Concrete block (CMU) foundation wall, regular weight, solid, 8" thick, 2 courses tall	750.00	L.F.	$21.15	$15,607.50
B20101525150	E.I.F.S., plywood sheathing, 1x8 fascia, R8 insulation, stud wall, 2" x 6", 16" O.C., 2" EPS	23,500.00	S.F.	$12.54	$333,935.00
B20201066650	Windows, aluminum, sliding, standard glass, 5' x 3'	80.00	Ea.	$446.28	$35,702.40
B20202101150	Aluminum flush tube frame, for 1/4"glass,1-3/4"x4", 5'x6' opening, 1 intermediate horizontal	500.00	S.F.	$30.00	$15,000.00
B20202202450	Glazing panel, plate glass, 1/2" thick, tempered	600.00	S.F.	$45.22	$27,132.00
B20301106500	Door, aluminum & glass, without transom, full vision, hardware, 3'-0" x 7'-0" opening	2.00	Opng.	$4,826.40	$9,652.80
B30101203300	Roofing, single ply membrane, EPDM, 60 mils, fully adhered	10,516.00	S.F.	$1.92	$20,190.72
B30103202700	Insulation, rigid, roof deck, extruded polystyrene, 40 PSI compressive strength, 6" thick, R30	10,516.00	S.F.	$6.07	$60,677.32
B30103202750	Insulation, rigid, roof deck, extruded polystyrene, 40 PSI, tapered for drainage	10,516.00	S.F.	$1.38	$14,512.08
B30104101100	Base flashing, aluminum, .050" thick, mill finish, .025" aluminum reglet, .032" counter flashing	440.00	L.F.	$27.09	$11,919.60
B-CEIL-ACT	Acoustic Drop Ceiling	5,000.00	S.F.	$6.33	$30,050.00

B-CONN-WOOD	Holdown Connectors for Wood Construction	150.00	Ea.	$92.63	$14,001.00
B-CWL-WD6	Wood Corridor Wall Version	16,000.00	S.F.	$17.61	$281,280.00
B-DWL-WD6	Wood Demising Wall Version 1	17,500.00	S.F.	$23.75	$413,175.00
B-EWL-WD6	Wood Exterior Wall	22,379.00	S.F.	$19.73	$445,789.68
B-FLR-WD	Wood floor, TJI Floor Joist	32,068.00	S.F.	$25.24	$815,809.92
B-HANG-WOOD	Joist Hangers for Wood Construction	850.00	Ea.	$3.38	$2,890.00
B-PWL-WD4	Wood 4 inch Interior Partitions	19,951.00	S.F.	$8.51	$164,994.77
B-RF-WD	TJI Roof	41,500.00	S.F.	$15.05	$617,105.00
B-RIMJ-WOOD	Rim Joist and Insulation for Wood Construction	1,350.00	L.F.	$17.76	$8,653.50
B-STLCOL-WD	Steel Columns for Wood Construction	438.00	L.F.	$40.97	$18,448.56
B-SWL-CMU8	8" CMU Shaft wall	4,500.00	S.F.	$13.02	$56,070.00
B-W24x76	Structural steel beam W24x76	1,850.00	L.F.	$135.74	$258,981.50
C10201145020	Metal door/metal frame, flush-hollow core, 16 ga full panel, 3'-0" x 7'-0", butt weld frame, 8-3/4"	97.00	Ea.	$1,534.65	$148,861.05
C10201203200	Wood door/wood frame, particle core/flush, birch face, 3'-0" x 7'-0", pine frame, 3-5/8"	97.00	Ea.	$539.12	$52,294.64
C10308300110	Cabinets, residential, base, hardwood, 1 top drawer & 1 door below x 12" W	325.00	Ea.	$367.96	$119,587.00
C10308300160	Cabinets, residential, counter top-laminated plastic, custom-square edge, 7/8" thick	325.00	L.F.	$39.82	$12,941.50
C20101101120	Stairs, wood, prefab box type, oak treads, wood rails 3'-6" wide, 14 risers	12.00	Ea.	$2,459.23	$29,510.76
C30102301960	Ceramic tile, thin set, 12" x 12"	2,600.00	S.F.	$8.34	$21,684.00
C30204100140	Carpet, tufted, nylon, roll goods, 12' wide, 26 oz	35,000.00	S.F.	$2.33	$81,550.00
C30204100220	Carpet, padding, add to above, 2.7 density	35,032.00	S.F.	$0.93	$32,579.76
C30204101720	Tile, ceramic natural clay	6,569.00	S.F.	$8.87	$58,267.03
C30204109200	Vinyl, composition tile, 12" x 12" x 1/8" thick, recycled content	14,597.00	S.F.	$3.19	$46,564.43

C30301105100	Gypsum board ceilings, 5/8" fire rated gypsum board, painted and textured finish,1" x 3" wood, 16" OC furring, wood support	36,500.00	S.F.	$4.28	$152,205.00
D10101401600	Traction geared elevators, passenger, 2500 lb., 5 floors, 200 FPM	2.00	Ea.	$205,905.32	$413,140.24
D20109267080	Bathroom, three fixture, 2 wall plumbing, lavatory, corner stall shower & water closet, stand alone	88.00	Ea.	$6,399.30	$563,138.40
D20202502220	Gas fired water heater, commercial, 100 F rise, 500 MBH input, 480 GPH	4.00	Ea.	$29,938.90	$119,755.60
D40104101080	Wet pipe sprinkler systems, steel, ordinary hazard, 1 floor, 10,000 SF	13,790.00	S.F.	$4.00	$55,160.00
D40104101220	Wet pipe sprinkler systems, steel, ordinary hazard, each additional floor, 10,000 SF	30,000.00	S.F.	$3.20	$96,000.00
D40203101580	Wet standpipe risers, class III, steel, black, sch 40, 6" diam pipe, 1 floor	1.00	Floor	$15,603.40	$15,603.40
D40203101600	Wet standpipe risers, class III, steel, black, sch 40, 6" diam pipe, additional floors	3.00	Floor	$3,958.70	$11,876.10
D40204103650	Fire pump, electric, with controller, 5" pump, 100 HP, 1000 GPM	1.00	Ea.	$40,788.80	$40,788.80
D50101301050	Underground service installation, includes excavation, backfill, and compaction, 100' length, 4' depth, 3 phase, 4 wire, 277/480 volts, 2000 A, groundfault switchboard	1.00	Ea.	$89,461.00	$89,461.00
D50102400400	Switchgear installation, incl switchboard, panels & circuit breaker, 120/208 V, 3 phase, 2000 A	1.00	Ea.	$42,109.20	$42,109.20
D50102501000	Panelboard, 4 wire w/conductor & conduit, NQOD, 120/208 V, 100 A, 0 stories, 0' horizontal	86.00	Ea.	$2,797.48	$240,583.28
D50201100600	Receptacles incl plate, box, conduit, wire, 16.5 per 1000 SF, 2.0 watts per SF	43,790.00	S.F.	$2.71	$118,670.90
D50201400240	Central air conditioning power, 3 watts	43,790.00	S.F.	$0.46	$20,143.40
D50202100200	Fluorescent fixtures recess mounted in ceiling, 1 watt per SF, 20 FC, 5 fixtures @40 watts per 1000 SF	43,790.00	S.F.	$2.07	$90,645.30
D50309100440	Communication and alarm systems, fire detection, non-addressable, 100 detectors, includes outlets, boxes, conduit and wire	1.00	Ea.	$50,851.80	$50,851.80
D50309200102	Internet wiring, 2 data/voice outlets per 1000 S.F.	50.00	M.S.F.	$456.21	$22,810.50
D-HVAC-CONCA	Heating/cooling system , gas fired forced air, one zone, SEER 14, 1000 SF	0.00	Ea.	$5,121.41	$0.00
D-HVAC-WOODA	Heating/cooling system , gas fired forced air, one zone, SEER 14, 1000 SF Wood	88.00	Ea.	$5,121.41	$440,317.68

E10106100120	Architectural equipment, laundry equipment, dry cleaners, electric, 20 lb capacity	0.00	Ea.	$41,470.83	$0.00
E10106100170	Architectural equipment, laundry equipment, washers, commercial, coin operated, deluxe	0.00	Ea.	$4,222.10	$0.00
E10906100160	Architectural equipment, school equipment, weight lifting gym, universal, deluxe	1.00	Ea.	$17,995.95	$17,995.95
E20103100120	Furnishings, blinds, exterior, aluminum, louvered, 1'-4" wide x 6'-8" long	88.00	Ea.	$426.51	$37,532.88
E20202100300	Furnishings, hotel furnishings, standard room set, economy, per room	86.00	Ea.	$3,009.00	$258,774.00
E20202100510	Furnishings, office furniture, standard employee set, deluxe , per person	4.00	Ea.	$2,473.50	$9,894.00
G20202101620	Parking lot, 90 degree angle parking, 6" bituminous paving, 6" gravel base	0.00	Car	$1,944.67	$0.00
G-INS-CONC	Builder's Risk Insurance Concrete	0.00	Ea.	$1.00	$0.00
G-INS-WOOD	Builder's Risk Insurance Wood	26,163.00	Ea.	$1.00	$26,163.00
Category: 41_500 SF Reference Hotel - WOOD Subtotal					**$7,346,154.40**

Subtotal		**$7,346,154.40**
General Contractor's Markup on Subs	**0.00%**	**$0.00**
Subtotal		**$7,346,154.40**
General Conditions	**11.00%**	**$808,076.98**
Subtotal		**$8,154,231.38**
General Contractor's Overhead and Profit	**7.00%**	**$570,796.20**
Assembly Cost Total		**$8,725,027.58**
Grand Total		**$8,725,027.58**

Appendix 2: Detailed Cost Analysis for ICF & Precast Plank Flooring

Cost Estimate Report

Date: 04/28/2021

Prepared By:

Unit Detail Report by WBS

Unit Line Number	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Subtotal					
Subtotal					
General Contractor's Markup on Subs					
Subtotal					
General Conditions					
Subtotal					
General Contractor's Overhead and Profit					
Unit Cost Total					

Assembly Detail Report by WBS

Year 2021 Quarter 1

Assembly Number	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl.O&P
Category: 41_500 SF Reference Hotel - ICF PP					
A10101103300	Strip footing, concrete, reinforced, load 9.3 KLF, soil bearing capacity 3 KSF, 12" deep x 40" wide	1,145.00	L.F.	$45.41	$51,994.45
A10102107150	Spread footings, 3000 PSI concrete, load 50K, soil bearing capacity 3 KSF, 4' - 6" square x 12" deep	10.00	Ea.	$292.57	$2,925.70
A10102107650	Spread footings, 3000 PSI concrete, load 200K, soil bearing capacity 3 KSF, 8' -6" square x 20" deep	16.00	Ea.	$1,344.07	$21,505.12
A10301202240	Slab on grade, 4" thick, non industrial, reinforced	11,723.00	S.F.	$4.75	$55,684.25
A20101105760	Excavate and fill, 30,000 SF, 4' deep, sand, gravel, or common earth, off site storage	12,000.00	S.F.	$0.33	$3,960.00
A-FWL-ICF	8" ICF foundation wall, 1.5' tall	750.00	L.F.	$18.57	$14,077.50
B20101525252	E.I.F.S. system, applied existing sheathing	23,500.00	S.F.	$7.30	$203,745.00
B20201066650	Windows, aluminum, sliding, standard glass, 5' x 3'	80.00	Ea.	$446.28	$35,702.40
B20202101150	Aluminum flush tube frame, for 1/4"glass,1-3/4"x4", 5'x6' opening, 1 intermediate horizontal	500.00	S.F.	$30.00	$15,000.00
B20202202450	Glazing panel, plate glass, 1/2" thick, tempered	600.00	S.F.	$45.22	$27,132.00
B20301106500	Door, aluminum & glass, without transom, full vision, hardware, 3'-0" x 7'-0" opening	2.00	Opng.	$4,826.40	$9,652.80
B30101203300	Roofing, single ply membrane, EPDM, 60 mils, fully adhered	10,516.00	S.F.	$1.92	$20,190.72
B30103202700	Insulation, rigid, roof deck, extruded polystyrene, 40 PSI compressive strength, 6" thick, R30	10,516.00	S.F.	$6.07	$60,677.32
B30103202750	Insulation, rigid, roof deck, extruded polystyrene, 40 PSI, tapered for drainage	10,516.00	S.F.	$1.38	$14,512.08
B30104101100	Base flashing, aluminum, .050" thick, mill finish, .025" aluminum reglet, .032" counter flashing	440.00	L.F.	$27.09	$11,919.60
B-CEIL-ACT	Acoustic Drop Ceiling	5,000.00	S.F.	$6.33	$30,050.00
B-CWL-ICF6	6 inch ICF corridor wall	16,000.00	S.F.	$19.47	$311,040.00
B-DWL-ICF6	6 inch ICF demising wall	17,500.00	S.F.	$16.69	$291,900.00

B-EWL-ICF6	6 inch ICF exterior wall	22,379.00	S.F.	$19.03	$428,557.85
B-FLR-PC8+2	Precast concrete plank, 2" topping, 10" total thickness, 30' span, 40 PSF superimposed load, 120 PSF total load	32,068.00	S.F.	$27.42	$870,646.20
B-RF-HC8	8" Hollow Core Precast Roof	10,516.00	S.F.	$25.32	$260,481.32
B-SWL-ICF6	6" ICF Shaft wall	5,194.00	S.F.	$18.54	$96,192.88
B-W16x31	Structural steel beam W12x14	667.00	L.F.	$58.66	$40,313.48
C10101265070	Metal partition, 5/8"fire rated gypsum board face, no base layer, 3-5/8" @ 16", 5/8" regular gypsum board opposite face, no insulation	26,601.00	S.F.	$6.78	$176,098.62
C10201145020	Metal door/metal frame, flush-hollow core, 16 ga full panel, 3'-0" x 7'-0", butt weld frame, 8-3/4"	97.00	Ea.	$1,534.65	$148,861.05
C10201203200	Wood door/wood frame, particle core/flush, birch face, 3'-0" x 7'-0", pine frame, 3-5/8"	97.00	Ea.	$539.12	$52,294.64
C10308300110	Cabinets, residential, base, hardwood, 1 top drawer & 1 door below x 12" W	325.00	Ea.	$367.96	$119,587.00
C10308300160	Cabinets, residential, counter top-laminated plastic, custom-square edge, 7/8" thick	325.00	L.F.	$39.82	$12,941.50
C20101100560	Stairs, CIP concrete, w/landing, 12 risers, with nosing	12.00	Flight	$4,329.23	$51,950.76
C30102301960	Ceramic tile, thin set, 12" x 12"	2,600.00	S.F.	$8.34	$21,684.00
C30204100140	Carpet, tufted, nylon, roll goods, 12' wide, 26 oz	35,032.00	S.F.	$2.33	$81,624.56
C30204100220	Carpet, padding, add to above, 2.7 density	35,032.00	S.F.	$0.93	$32,579.76
C30204101720	Tile, ceramic natural clay	6,569.00	S.F.	$8.87	$58,267.03
C30204102100	Prefinished white oak, prime grade, 3-1/4" wide	14,597.00	S.F.	$8.86	$129,329.42
C30301105700	Gypsum board ceilings, 5/8" fire rated gypsum board, painted and textured finish,1-5/8" metal stud furring, 24" OC support	36,500.00	S.F.	$2.69	$98,185.00
C30302105800	Acoustic ceilings, 5/8" fiberglass board, 24" x 48" tile, tee grid, suspended support	36,500.00	S.F.	$1.84	$74,460.00
D10101401600	Traction geared elevators, passenger, 2500 lb., 5 floors, 200 FPM	2.00	Ea.	$205,905.32	$413,140.24
D20109267080	Bathroom, three fixture, 2 wall plumbing, lavatory, corner stall shower & water closet, stand alone	88.00	Ea.	$6,399.30	$563,138.40
D20202502220	Gas fired water heater, commercial, 100 F rise, 500 MBH input, 480 GPH	4.00	Ea.	$29,938.90	$119,755.60

D40104101080	Wet pipe sprinkler systems, steel, ordinary hazard, 1 floor, 10,000 SF	13,790.00	S.F.	$4.00	$55,160.00
D40104101220	Wet pipe sprinkler systems, steel, ordinary hazard, each additional floor, 10,000 SF	30,000.00	S.F.	$3.20	$96,000.00
D40203101580	Wet standpipe risers, class III, steel, black, sch 40, 6" diam pipe, 1 floor	1.00	Floor	$15,603.40	$15,603.40
D40203101600	Wet standpipe risers, class III, steel, black, sch 40, 6" diam pipe, additional floors	3.00	Floor	$3,958.70	$11,876.10
D40204103650	Fire pump, electric, with controller, 5" pump, 100 HP, 1000 GPM	1.00	Ea.	$40,788.80	$40,788.80
D50101301050	Underground service installation, includes excavation, backfill, and compaction, 100' length, 4' depth, 3 phase, 4 wire, 277/480 volts, 2000 A, groundfault switchboard	1.00	Ea.	$89,461.00	$89,461.00
D50102400400	Switchgear installation, incl switchboard, panels & circuit breaker, 120/208 V, 3 phase, 2000 A	1.00	Ea.	$42,109.20	$42,109.20
D50102501000	Panelboard, 4 wire w/conductor & conduit, NQOD, 120/208 V, 100 A, 0 stories, 0' horizontal	86.00	Ea.	$2,797.48	$240,583.28
D50201100600	Receptacles incl plate, box, conduit, wire, 16.5 per 1000 SF, 2.0 watts per SF	43,790.00	S.F.	$2.71	$118,670.90
D50201400240	Central air conditioning power, 3 watts	43,790.00	S.F.	$0.46	$20,143.40
D50202100200	Fluorescent fixtures recess mounted in ceiling, 1 watt per SF, 20 FC, 5 fixtures @40 watts per 1000 SF	43,790.00	S.F.	$2.07	$90,645.30
D50309100440	Communication and alarm systems, fire detection, non-addressable, 100 detectors, includes outlets, boxes, conduit and wire	1.00	Ea.	$50,851.80	$50,851.80
D50309200102	Internet wiring, 2 data/voice outlets per 1000 S.F.	50.00	M.S.F.	$456.21	$22,810.50
D-HVAC-CONCA	Heating/cooling system , gas fired forced air, one zone, SEER 14, 1000 SF	77.40	Ea.	$5,121.41	$387,279.41
D-HVAC-WOODA	Heating/cooling system , gas fired forced air, one zone, SEER 14, 1000 SF Wood	0.00	Ea.	$5,121.41	$0.00
E10106100120	Architectural equipment, laundry equipment, dry cleaners, electric, 20 lb capacity	0.00	Ea.	$41,470.83	$0.00
E10106100170	Architectural equipment, laundry equipment, washers, commercial, coin operated, deluxe	0.00	Ea.	$4,222.10	$0.00
E10906100160	Architectural equipment, school equipment, weight lifting gym, universal, deluxe	1.00	Ea.	$17,995.95	$17,995.95
E20103100120	Furnishings, blinds, exterior, aluminum, louvered, 1'-4" wide x 6'-8" long	88.00	Ea.	$426.51	$37,532.88

E20202100300	Furnishings, hotel furnishings, standard room set, economy, per room	86.00	Ea.	$3,009.00	$258,774.00
E20202100510	Furnishings, office furniture, standard employee set, deluxe , per person	4.00	Ea.	$2,473.50	$9,894.00
G-INS-CONC	Builder's Risk Insurance Concrete	11,900.00	Ea.	$1.00	$11,900.00
G-INS-WOOD	Builder's Risk Insurance Wood	0.00	Ea.	$1.00	$0.00
Category: 41_500 SF Reference Hotel - ICF PP Subtotal					**$6,649,838.17**

Subtotal		**$6,649,838.17**
General Contractor's Markup on Subs	**0.00%**	**$0.00**
Subtotal		**$6,649,838.17**
General Conditions	**15.00%**	**$997,475.73**
Subtotal		**$7,647,313.90**
General Contractor's Overhead and Profit	**7.00%**	**$535,311.97**
Assembly Cost Total		**$8,182,625.87**
Grand Total		**$8,182,625.87**

Appendix 3: Detailed Cost Analysis for ICF & Composite Concrete Flooring Deck

Cost Estimate Report

Date: 04/28/2021

Prepared By:

Unit Detail Report by WBS

Unit Line Number	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl. O&P
Subtotal					
Subtotal					
General Contractor's Markup on Subs					
Subtotal					
General Conditions					
Subtotal					
General Contractor's Overhead and Profit					
Unit Cost Total					

Assembly Detail Report by WBS

Year 2021 Quarter 1

Assembly Number	Description	Quantity	Unit	Total Incl. O&P	Ext. Total Incl.O&P
Category: 41_500 SF Reference Hotel - ICF Composite Concrete FS					
A10101103300	Strip footing, concrete, reinforced, load 9.3 KLF, soil bearing capacity 3 KSF, 12" deep x 40" wide	1,145.00	L.F.	$45.41	$51,994.45
A10102107150	Spread footings, 3000 PSI concrete, load 50K, soil bearing capacity 3 KSF, 4' - 6" square x 12" deep	10.00	Ea.	$292.57	$2,925.70
A10102107650	Spread footings, 3000 PSI concrete, load 200K, soil bearing capacity 3 KSF, 8' -6" square x 20" deep	16.00	Ea.	$1,344.07	$21,505.12
A10301202240	Slab on grade, 4" thick, non industrial, reinforced	11,723.00	S.F.	$4.75	$55,684.25
A20101105760	Excavate and fill, 30,000 SF, 4' deep, sand, gravel, or common earth, off site storage	12,000.00	S.F.	$0.33	$3,960.00
A-FWL-ICF	8" ICF foundation wall, 1.5' tall	750.00	L.F.	$18.58	$14,077.50
B20101525252	E.I.F.S. system, applied existing sheathing	23,500.00	S.F.	$7.30	$203,745.00
B20201066650	Windows, aluminum, sliding, standard glass, 5' x 3'	80.00	Ea.	$446.28	$35,702.40
B20202101150	Aluminum flush tube frame, for 1/4"glass,1-3/4"x4", 5'x6' opening, 1 intermediate horizontal	500.00	S.F.	$30.00	$15,000.00
B20202202450	Glazing panel, plate glass, 1/2" thick, tempered	600.00	S.F.	$45.22	$27,132.00
B20301106500	Door, aluminum & glass, without transom, full vision, hardware, 3'-0" x 7'-0" opening	2.00	Opng.	$4,826.40	$9,652.80
B30101203300	Roofing, single ply membrane, EPDM, 60 mils, fully adhered	10,516.00	S.F.	$1.92	$20,190.72
B30103202700	Insulation, rigid, roof deck, extruded polystyrene, 40 PSI compressive strength, 6" thick, R30	10,516.00	S.F.	$6.07	$60,677.32
B30103202750	Insulation, rigid, roof deck, extruded polystyrene, 40 PSI, tapered for drainage	10,516.00	S.F.	$1.38	$14,512.08
B30104101100	Base flashing, aluminum, .050" thick, mill finish, .025" aluminum reglet, .032" counter flashing	440.00	L.F.	$27.09	$11,919.60
B-CEIL-ACT	Acoustic Drop Ceiling	5,000.00	S.F.	$6.33	$30,050.00
B-CWL-ICF6	6 inch ICF corridor wall	16,000.00	S.F.	$19.47	$311,040.00
B-DWL-ICF6	6 inch ICF demising wall	17,500.00	S.F.	$16.69	$291,900.00

B-EWL-ICF6	6 inch ICF exterior wall	22,379.00	S.F.	$19.03	$428,557.85
B-FLR-CCFS	Speedfloor system, light gauge galvanized steel, 12" to 18" deep, 48" spacing, 28' span, 3-1/2" 3000 psi concrete slab on plywood forms, 125 psf superimposed load, 5/8" gy	41,500.00	S.F.	$23.88	$991,020.00
B-SWL-ICF6	6" ICF Shaft wall	5,194.00	S.F.	$18.54	$96,192.88
B-W16x31	Structural steel beam W12x14	667.00	L.F.	$58.66	$40,313.48
C10101265070	Metal partition, 5/8"fire rated gypsum board face, no base layer, 3-5/8" @ 16", 5/8" regular gypsum board opposite face, no insulation	26,601.00	S.F.	$6.78	$176,098.62
C10201145020	Metal door/metal frame, flush-hollow core, 16 ga full panel, 3'-0" x 7'-0", butt weld frame, 8-3/4"	97.00	Ea.	$1,534.65	$148,861.05
C10201203200	Wood door/wood frame, particle core/flush, birch face, 3'-0" x 7'-0", pine frame, 3-5/8"	97.00	Ea.	$539.12	$52,294.64
C10308300110	Cabinets, residential, base, hardwood, 1 top drawer & 1 door below x 12" W	325.00	Ea.	$367.96	$119,587.00
C10308300160	Cabinets, residential, counter top-laminated plastic, custom-square edge, 7/8" thick	325.00	L.F.	$39.82	$12,941.50
C20101100560	Stairs, CIP concrete, w/landing, 12 risers, with nosing	12.00	Flight	$4,329.23	$51,950.76
C30102301960	Ceramic tile, thin set, 12" x 12"	2,600.00	S.F.	$8.34	$21,684.00
C30204100140	Carpet, tufted, nylon, roll goods, 12' wide, 26 oz	35,032.00	S.F.	$2.33	$81,624.56
C30204100220	Carpet, padding, add to above, 2.7 density	35,032.00	S.F.	$0.93	$32,579.76
C30204101720	Tile, ceramic natural clay	6,569.00	S.F.	$8.87	$58,267.03
C30204102100	Prefinished white oak, prime grade, 3-1/4" wide	14,597.00	S.F.	$8.86	$129,329.42
D10101401600	Traction geared elevators, passenger, 2500 lb., 5 floors, 200 FPM	2.00	Ea.	$205,905.32	$413,140.24
D20109267080	Bathroom, three fixture, 2 wall plumbing, lavatory, corner stall shower & water closet, stand alone	88.00	Ea.	$6,399.30	$563,138.40
D20202502220	Gas fired water heater, commercial, 100 F rise, 500 MBH input, 480 GPH	4.00	Ea.	$29,938.90	$119,755.60
D40104101080	Wet pipe sprinkler systems, steel, ordinary hazard, 1 floor, 10,000 SF	13,790.00	S.F.	$4.00	$55,160.00
D40104101220	Wet pipe sprinkler systems, steel, ordinary hazard, each additional floor, 10,000 SF	30,000.00	S.F.	$3.20	$96,000.00
D40203101580	Wet standpipe risers, class III, steel, black, sch 40, 6" diam pipe, 1 floor	1.00	Floor	$15,603.40	$15,603.40

D40203101600	Wet standpipe risers, class III, steel, black, sch 40, 6" diam pipe, additional floors	3.00	Floor	$3,958.70	$11,876.10
D40204103650	Fire pump, electric, with controller, 5" pump, 100 HP, 1000 GPM	1.00	Ea.	$40,788.80	$40,788.80
D50101301050	Underground service installation, includes excavation, backfill, and compaction, 100' length, 4' depth, 3 phase, 4 wire, 277/480 volts, 2000 A, groundfault switchboard	1.00	Ea.	$89,461.00	$89,461.00
D50102400400	Switchgear installation, incl switchboard, panels & circuit breaker, 120/208 V, 3 phase, 2000 A	1.00	Ea.	$42,109.20	$42,109.20
D50102501000	Panelboard, 4 wire w/conductor & conduit, NQOD, 120/208 V, 100 A, 0 stories, 0' horizontal	86.00	Ea.	$2,797.48	$240,583.28
D50201100600	Receptacles incl plate, box, conduit, wire, 16.5 per 1000 SF, 2.0 watts per SF	43,790.00	S.F.	$2.71	$118,670.90
D50201400240	Central air conditioning power, 3 watts	43,790.00	S.F.	$0.46	$20,143.40
D50202100200	Fluorescent fixtures recess mounted in ceiling, 1 watt per SF, 20 FC, 5 fixtures @40 watts per 1000 SF	43,790.00	S.F.	$2.07	$90,645.30
D50309100440	Communication and alarm systems, fire detection, non-addressable, 100 detectors, includes outlets, boxes, conduit and wire	1.00	Ea.	$50,851.80	$50,851.80
D50309200102	Internet wiring, 2 data/voice outlets per 1000 S.F.	50.00	M.S.F.	$456.21	$22,810.50
D-HVAC-CONCA	Heating/cooling system , gas fired forced air, one zone, SEER 14, 1000 SF	77.40	Ea.	$5,121.41	$387,279.41
D-HVAC-WOODA	Heating/cooling system , gas fired forced air, one zone, SEER 14, 1000 SF Wood	0.00	Ea.	$5,121.41	$0.00
E10106100120	Architectural equipment, laundry equipment, dry cleaners, electric, 20 lb capacity	0.00	Ea.	$41,470.83	$0.00
E10106100170	Architectural equipment, laundry equipment, washers, commercial, coin operated, deluxe	0.00	Ea.	$4,222.10	$0.00
E10906100160	Architectural equipment, school equipment, weight lifting gym, universal, deluxe	1.00	Ea.	$17,995.95	$17,995.95
E20103100120	Furnishings, blinds, exterior, aluminum, louvered, 1'-4" wide x 6'-8" long	88.00	Ea.	$426.51	$37,532.88
E20202100300	Furnishings, hotel furnishings, standard room set, economy, per room	86.00	Ea.	$3,009.00	$258,774.00
E20202100510	Furnishings, office furniture, standard employee set, deluxe , per person	4.00	Ea.	$2,473.50	$9,894.00
G-INS-CONC	Builder's Risk Insurance Concrete	11,900.00	Ea.	$1.00	$11,900.00

G-INS-WOOD	Builder's Risk Insurance Wood	0.00	Ea.	$1.00	$0.00

Category: 41_500 SF Reference Hotel - ICF Composite Concrete FS Subtotal **$6,337,085.65**

Subtotal		**$6,337,085.65**
General Contractor's Markup on Subs	**0.00%**	**$0.00**
Subtotal		**$6,337,085.65**
General Conditions	**15.00%**	**$950,562.85**
Subtotal		**$7,287,648.50**
General Contractor's Overhead and Profit	**7.00%**	**$510,135.40**
Assembly Cost Total		**$7,797,783.90**

Grand Total **$7,797,783.90**