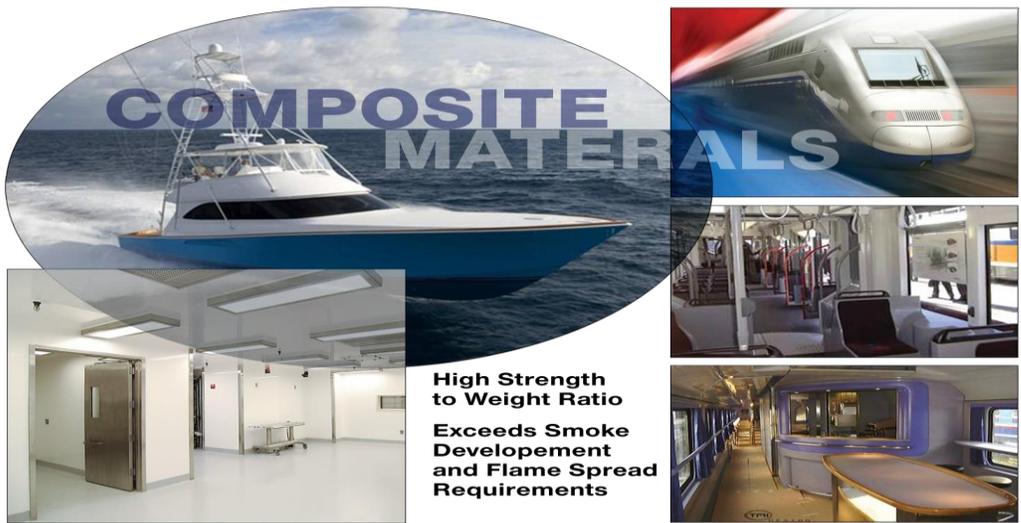


The Life Cycle Cost of Interior Finishes in High Containment Facilities and the Significance of Arcoplast Fiberglass Reinforced Polymer Composite Panels

Fiberglass reinforced composites are used in a wide range of applications in today's marketplace. They are now commonly used in the recreational, transportation and chemical industries to address a multitude of challenges presented by conventional building materials, including weight, structural strength, and chemical resistance. Manufacturers in these industries use fiberglass reinforced composites because they find them to be more efficient, cost effective and sustainable.



The same challenges are present in architectural applications. The need for lightweight, structurally sound, chemical resistant, sustainable products is ever growing. And, in the past 40 years there has been a great deal of advancement in the development of materials for both interior and exterior architectural applications.

Today, fiberglass reinforced composites such as Arcoplast may be engineered with specific properties in mind, such as tensile, flexural, and compressive strength. This enables architects and engineers to design environmentally controlled spaces with extreme capabilities, adapt to new installation methods and provide a service life which is matched only by the life expectancy of the building.

Several critically important factors should be considered when selecting interior finishes for the construction of biosafety laboratories, high containment facilities and mission critical environments: performance, design flexibility, ease of installation, maintenance, reliability, and longevity. And, due to the ever-present reality of budget constraints, cost is equally as important.

In this paper, we will compare the features, benefits, predictability, and reliability of the six most commonly used interior finishes in containment facility construction. We will examine their initial capital costs, maintenance costs and potential replacement costs, the sum of which ultimately leads to the total cost of ownership.

We will highlight Arcoplast architectural wall and ceiling panels and demonstrate how they are the best choice for the design, construction, and long-term performance of these environments.

Interior Finish System Options

The most used interior finish systems used in the construction of high containment facilities include:

1. Light gauge construction with drywall and high-performance coatings
2. Stainless steel panel system
3. Masonry block with high performance coatings
4. Masonry glazed block
5. Cast in place concrete with high performance coatings
6. Cast in place concrete with Arcoplast liner panel system
7. Light gauge construction with Arcoplast fiberglass reinforced polymer composite panel system

When the requirements for environmental performance are essential, the cost of the materials increases dramatically. Yet even with the highest cost materials and methods, there may be a sense of unpredictability in the construction process. Variability during the construction process is the most difficult issue that architects, engineers, and lab planners must face.

Table 1 Provides a score card for Total Performance Value Rating when reviewing preliminary design of High Containment Facilities mission critical environments.

High Containment Facility Total Performance Value Rating

	Initial Design Compatibility	Architectural/ Engineering Time 1	Architectural/ Engineering Time 2	Project Construction Costs 3	Project Construction Time 4	Construction Costs 5	Structure Compatibility 6	LEED Sustainability 7	Environmental 8	M. E. P. Compliancy 9	Material Compatibility 10	Maintenance Cost/ Yr 11	System Seal Integrity/ Life Cycle 12	Surface Properties 13	Decontamination/ Sanitation Capacity 14	S.T.C./N.R.C. (Sound/ Noise) 15	Flame Spread, Smoke, Toxicity 16	Air Pressure Cycle Movement 17	Ergonomics/ Environmental Impact 18	Facility Reliability 19	TOTAL POINTS (Possible 100)
Cast In-Place 12" Concrete Wall w/25 mils HPC	1	2	1	1	1	2	1	4	5	5	2	3	4	4	4	5	4	5	4	4	58
12" Thick CMU w/15 mils HPC	3	4	4	3	4	3	2	4	3	2	3	3	3	3	3	3	4	4	3	3	62
12" Thick Structural Glazed CMU	3	4	4	3	4	3	2	4	3	3	3	3	3	3	3	3	5	4	4	3	64
2" 18 Gauge Insulated Stainless Steel Panel	3	3	4	3	2	3	3	3	3	3	2	4	3	3	3	5	4	3	3	3	61
LG Steel Stud 1/2 Ea. Side w/15 mils HPC	4	5	5	4	5	4	3	4	2	3	2	2	3	2	2	3	4	3	3	2	61
Cast In-Place 8" Concrete Wall w/Arcoplast Liner Panel	1	2	1	1	2	2	1	3	5	5	2	5	5	5	5	5	4	5	5	5	68
Arcoplast w/LG Steel Stud	5	5	5	5	3	5	5	3	5	5	5	5	5	5	5	5	4	4	5	5	89

Rating Scale: 1 = Least Favorable to 5 = Most Favorable

1. Total Ability of Design of Facility, New or Existing.
2. Architectural/Engineering Time for Final Construction Documentation.
3. Architectural/Engineering Cost which includes Code Issues and Permitting.
4. Project Construction Time from Start to Finish.
5. Project Construction Costs which includes Cost of Materials plus Actual Labor Costs.
6. Construction Compatibility. The ease of construction on New and Existing Facilities.
7. Structure Assessment, New or Existing. Additional costs (time, professional, materials, etc.)
8. Leed Sustainability. Total performance in metrics such as savings, efficiency, emissions, environmental quality, and their impacts.
9. Performance in any and all Outside Influenced Environmental Situations (Flood Hazzard areas, Hurricane/Tornado Hazzard areas, High Risk areas, etc.)
10. M. E. P. Compliancy. Ability to provide Mechanicals, Electricals, and Plumbing systems in New or Existing Facilities which includes lifecycle costs (maintenance).
11. The Flexibility to use the Construction System/Materials for any of the Biosafety Facility Levels (BSL-1, BSL-2, BSL-3, BSL-3E, BSL-3AG, & BSL-4)
12. Maintenance Cost of Facility/System per Year.
13. System Seal Integrity/Life Cycle. Transition Areas Sealant Longevity, Penetration Sealant Performance.
14. Surface Properties. The Finished Product Surface Properties/Condition. Not only after the intial install but years after installation.
15. Decontamination/Sanitation Capacity. Ability to perform Decontamination/Sanitation with little or no ill effects, especially after years of use.
16. S.T.C./N.R.C. (Sound/Noise). Ratings for Sound and Noise Transmission. This includes the total construction method(s).
17. Flame Spread, Smoke, Toxicity. Ratings for Flame Spread, Smoke, Toxicity for Materials. This includes the total construction method(s).
18. Air Pressure Cycle Movement. Durability from Air Pressure Cycles of the Facility through the lifecycle.
19. Ergonomics/ Environmental Impact. Ease of use for all involved in day to day usage/operations and maintenance.
20. Facility Reliability which includes the Total Performance Value of the Method of Construction (Materials, Usability, Viewability, Costs, Maintenance, Etc.).

Light gauge construction with drywall and epoxy paints

Drywall offers great flexibility and ease in the design and construction phases, and it is also one of the cheaper options available. However, because drywall is easily affected by moisture, chemicals, temperatures, etc., it requires the addition of a high-performance surface coating. This introduces a host of variables to the project, each of which brings a risk of failure. The surface coatings must be applied in the proper thickness, the perfect mix ratio, and the proper environmental conditions to the ideal substrate. A single inconsistency may later result in blistering, pin holes, cracking, chipping, etc., crippling a facility almost instantly. And you will not know *until* it happens.

Stainless steel panel system

Stainless steel panels have the advantage of a surface produced under exacting conditions, yet they lack the design flexibility of other methods, increasing the complexity and cost of a facility. Continuous welding of stainless steel joints is an impractical and costly task, so gasket-type joints are utilized. While airtight, they are not seamless and will produce problem areas for potential contamination and a constant source of maintenance. Stainless steel also creates a drab environment by soaking up a room's candlelight, and it needs regular buffing and polishing to keep its finish from becoming dull. There are no means of reasonable repair, with dents and scratches becoming part of the décor. The harsh disinfecting solutions used in the facilities may

also adversely react with some stainless steel finishes, furthering the lack of professional appeal and potentially causing irreparable damage to the surface. Before long, a costly remodel will be necessary.

Masonry block with high performance coatings (HPC)

Masonry block is an antiquated method that has been used for decades because of its durability and familiarity. However, masonry block adds substantial weight to a facility and generates an unpleasant “bunker” sensation. It also does not allow for chase wall construction without sacrificing additional floor space, so placing utilities inside of the wall cavity can be very challenging, while utilities and services outside of the barrier only create more housekeeping issues. The “wet” construction of masonry block increases risk, as mortar, fillers, sealants, and other liquids are present as a wall moves through its many phases of work. When the mortar joints have dried, sanding and smoothing are needed to create a flush finish and eliminate surface porosity, creating particulates in the environment. Throughout the process, more time passes, and labor costs intensify as the coordination of trades and thorough cleanups are needed to conduct this cumbersome dance. Then, adding the required surface coatings introduces many more variables to the project. After the project is complete, frequent grout repairs to the joints will be necessary due to building movement, leading to substantial maintenance costs and business interruptions.

Masonry glazed block

The finish on masonry glazed block is baked at the factory, so specialty coatings do not have to be applied. However, all of the other disadvantages of masonry block are still present: the substantial weight, the unpleasant “bunker” sensation, lack of opportunity for chase wall construction, the problems presented by “wet” construction, considerable maintenance costs, and business interruptions due to the continuous, necessary grout repair which will be necessary due to building movement.

Cast in place concrete with high performance coatings

Specially formulated concretes have traditionally been used when the walls and ceilings must function as a primary barrier, such as in BSL-3 Ag and BSL-4 laboratories. However, this is a design, cost, labor, and time-intensive method. Curing times for some concrete can take nearly one year before being ready to finish. The time factor alone swells to a point where it becomes financial lunacy. And the costs associated with almost any form of failure whether mechanically, chemically, or environmentally induced, could explode even a favorably robust budget.

Light gauge construction with Arcoplast Panel System

Arcoplast's patented fiberglass reinforced polymer composite, high gloss antimicrobial gel coat and finishing compound are the components of an incredible system that eliminates the risk of failure.

- Borrowed from the light gauge steel stud construction methods, Arcoplast fiberglass reinforced composite wall and ceiling systems do not require elaborate pre-engineering preparations in drawings and installation documents and interface well with typical building fixtures such as door and window frames, MEP's, flooring finishes, etc.

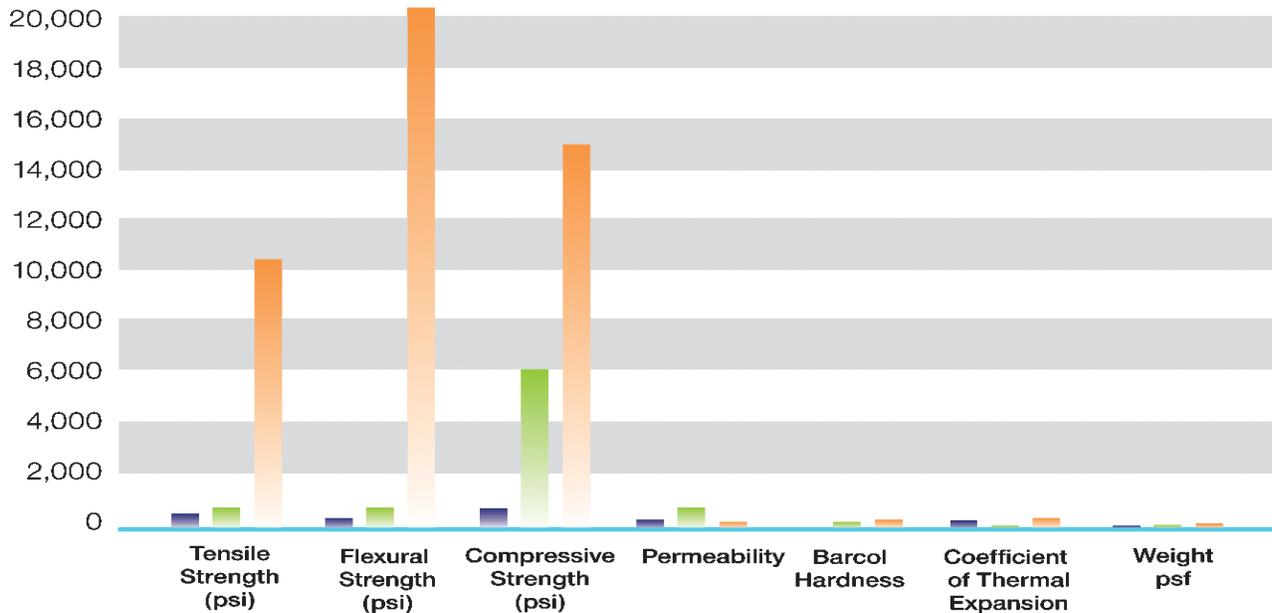
- Arcoplast panels are manufactured in modular panel board form that are cut, bored, and fastened in the field reducing engineering and fabrication time and costly project delays due to last minute order changes.
- Arcoplast has an extensive library of application drawings and installation details specifically adapted to the construction of high containment facilities.
- Arcoplast panels are permanently finished with a smooth, high gloss antimicrobial gel coat, requiring only one trade application and a dry construction environment.
- Arcoplast will withstand up to and greater than 30 years of vigorous decontamination or wash-downs. It will not decay, dent, fade, or peel, so it will never need to be painted or re-finished.
- Arcoplast is impervious to microorganisms, impermeable from the front and back, unaffected by moisture or temperature and cannot be attacked by insects or vermin. They are particularly well suited for flood hazard and coastal high-risk hazard areas.
- The use of Arcoplast Finishing Compound, which is equally as impermeable, results in an air, gas, and water vapor tight assembly. The process creates a smooth, seamless seal between panels and panel intersections that will not crack or deteriorate.
- Arcoplast systems are designed to outlast the life of the facility. They are impact, corrosion, and chemical resistant, and virtually indestructible.
- Arcoplast panels are available in a variety of thicknesses and dimensions up to 10'W x 40'L. They may be used with traditional steel studs and furring channels or attached to existing walls and ceilings. Superior strength to weight ratio and outstanding tensile and flexural strength yield extraordinary and unsurpassed results in a construction assembly.
- Arcoplast panels may be assembled in virtually any configuration, providing the ultimate in design flexibility and allowing for cost-effective "box-within-a-box" construction, walk-on ceilings, wall and ceiling liners, load bearing partitions, chase systems, beam covers and bulkheads. They can be easily adapted to new or existing construction and particularly well suited for high rise buildings.
- Arcoplast panels can perform as cavity-less free-standing partitions, which enable lab planners and architects to design suites for areas in which space and location is critical and for environments in which wall cavities are not suitable.
- Arcoplast's beautiful high gloss, bright white finish has been shown to produce a light reflectivity of 99.7 % at an 85 degree source angle, so a laboratory can be designed with fewer lamp fixtures, reducing the amount of penetrations to the ceiling surface and evenly diffusing the light throughout the room.

- Arcoplast meets and exceeds USDA, FDA, cGMP, BMBL 5th Edition, USP 797 Compliant, GLSP, NIH and CDC specific guidelines for maximum containment facilities.
- Arcoplast fiberglass polymer composite panels have the unique ability to integrate both shielding and barrier functions in a single finished product.
- Arcoplast is used in mission critical environments and BSL-3, BSL-3Ag and BSL-4 facilities. Our products excel on air pressure decay tests, keeping interior and exterior personnel safe from harmful pathogens.

Mechanical and Physical Properties

The mechanical and physical properties of building materials should be carefully considered when planning the construction of high containment facilities. Flexural and compressive strength, surface hardness, gloss property, coefficient of expansion and contraction, impact resistance and water vapor transmission are crucial factors in the material selection process. Disappointment and failures are, in many cases, associated with a poor performance of materials or systems design.

Mechanical and Physical Properties Comparison



	Gypsum	Concrete	Arcoplast
Tensile Strength (psi)	80	700	10,141
Flexural Strength (psi)	60	700	21,101
Compressive Strength (psi)	350	6,000	15,920
Permeability	31	6	0.01
Barcol Hardness	0	50	56.8
Coefficient of Thermal Expansion	9.3x10 ⁻⁶ in/in°F	5.5x10 ⁻⁶ in/in°F	27.5x10 ⁻⁶ in/in°F
Weight psf	1.4	4.5	3

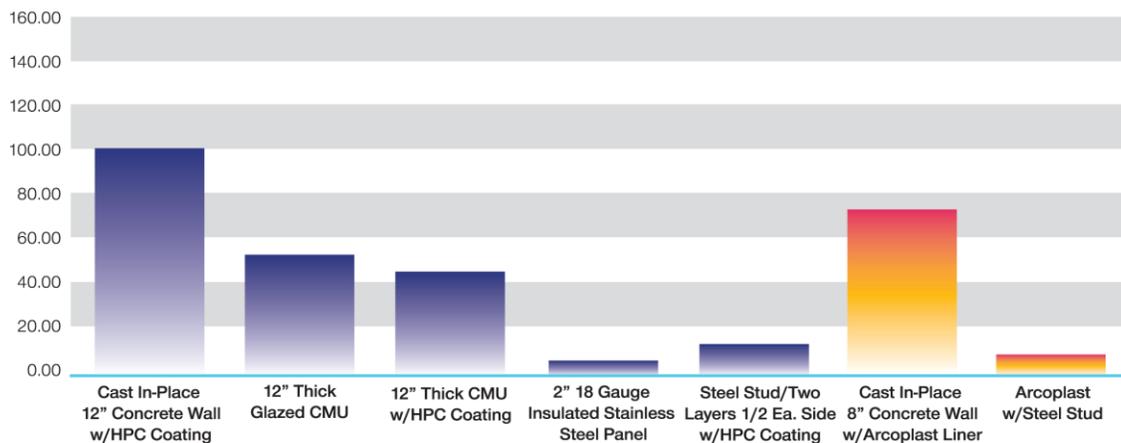
LEGEND	
■	Gypsum
■	Concrete
■	Arcoplast

Weight of Interior Finish Materials

The weight of building materials plays an essential role in the architecture, design, and engineering of a building, and equally a significant factor in the cost effectiveness of a project. Design and weight limitations, building movement and demanding construction schedules must be carefully assessed. The cost to reinforce a building's foundation and structure to support the added weight of interior wall and ceiling systems can be exceedingly expensive.

High Containment Facility Construction Estimated Material Weights

Pound/Square Foot



Consider this example: A wall to footprint ratio is approximately 1.72 feet times the floor surface. With a 5,000 square foot footprint, the laboratory space will yield approximately 8,600 square feet of partition surface.

Arcoplast Panel System: 7 lbs. x 8600 sq. ft. = 60,200 lbs.

Masonry Block: 45 lbs. x 8,600 sq. ft. = 387,000 lbs.

Poured in Place Concrete: 100 lbs. x 8,600 sq. ft. = 860,000 lbs.

At 7 pounds per square foot, Arcoplast panel systems would clearly cause the least stress on the building. The structural and environmental integrity is achieved through light gauge steel stud framing and Arcoplast modular panel system that work in harmony with the building movement, and constant air cycle movement generated by the air handling systems.

Chemical Resistance:

Environmental compliance in high containment facilities can be extremely challenging, particularly in regularly decontaminated spaces. Some surfaces may be initially sound, but may not be able to withstand constant, ongoing wash-downs or decontamination procedures. Or, a product may have excellent chemical resistance but poor mechanical and physical properties.

When building with drywall, masonry block or concrete, adding specialty coatings or grout may cause inconsistencies that could later result in blistering, pin holes, cracking, chipping, etc. The result cannot be verified until after extensive time, money and labor has been expended. In addition, the porosity of masonry and its joint weakness can be a source of constant maintenance and potential contamination issues.

Metals also do not fare well in highly caustic environments. Some stainless steel will corrode, and painted metals erode under constant high-pressure wash downs.

Arcoplast panels will withstand decades of vigorous decontamination or wash-downs. They will not decay, dent, fade, or peel, so their service life is designed to outlast the life of the building.

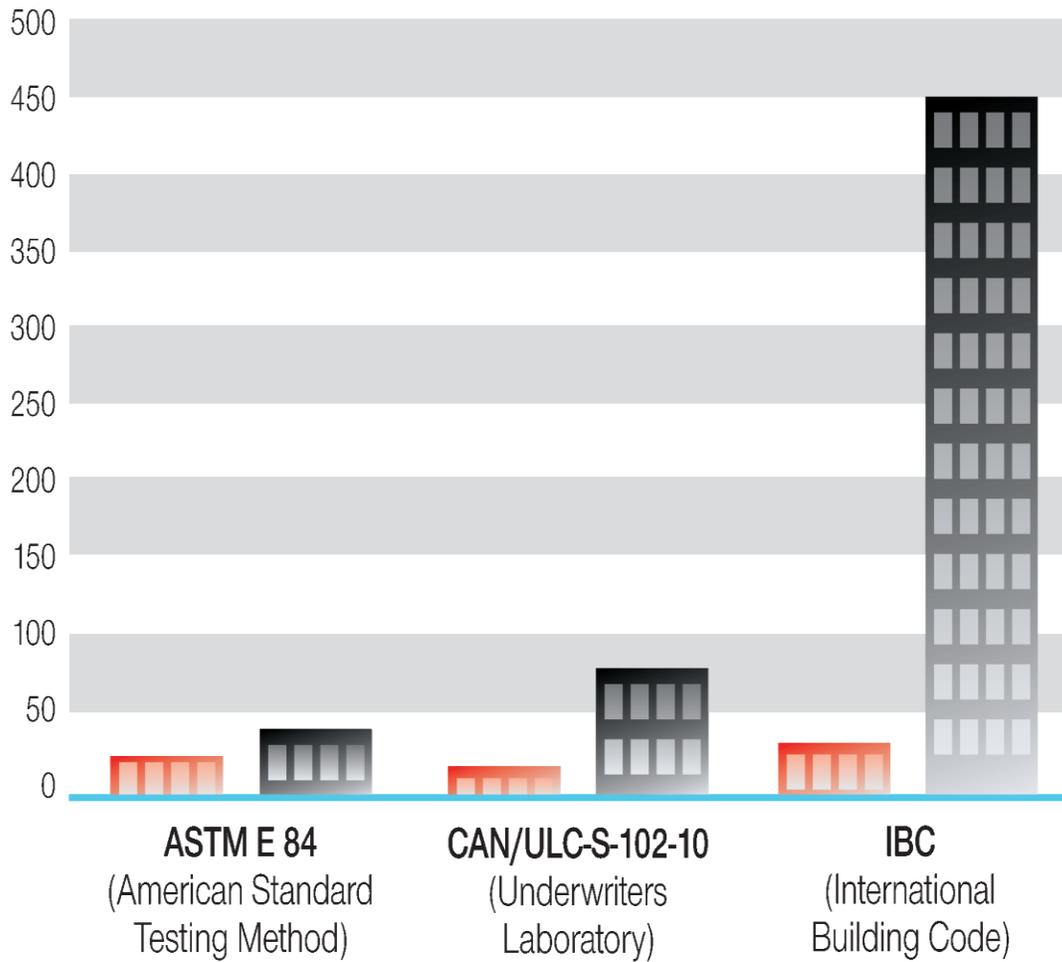
Fire and Smoke Classification:

In 2009 under the Plastic Chapter 26, the International Building Code (IBC) created a division which addresses fiberglass reinforced polymer composite materials. This enables architects, specifiers and building owners to clearly interpret and conform to a uniform building code.

Composite materials are not incombustible, however the combustibility level can be significantly reduced through proper chemistry engineering. The surface burning characteristics of building materials manufactured in the United States are tested per the (American Standard Testing Method) (ASTM-E 84). In Canada it is determined by Underwriters Laboratories S-102. In Europe, composite materials are tested in accordance with European Standard EN 13823, EN ISO 11925 and EN 13501.

Interior finishes are classified according to their flame spread and smoke spread development indexes.

Flame Spread and Smoke Development Classification



ARCOPLAST TEST	ASTM E 84	CAN/ULC-S-102-10	IBC
Flame Spread value (FSV)	22.5	18.8	25
Smoke Development (SDV)	39.9	63.4	450

LEGEND

- Flame Spread Value (FSV)
- Smoke Development (SDV)

Manufacturers usually publish the class only. However, there should be a more scrupulous look into the numbers. Owners and architects should require the test results for the flame and smoke generation to better assess the suitability of the interior finishes.

A composite material labeled as a Class A (Flame Spread 0-25) may not have a large margin of improvement because it is already in a low category. But, the (Smoke Development 0-450) is extremely critical, and a composite material with a smoke development of 425 versus 50 can have catastrophic consequences in a high occupancy high rise building.

Another area of concern is the toxicity issue in composite building materials. The City of New York requires testing on materials for acute lethality. This is based on the test methodology specified in the Building Code for the City of New York and as published by the University of Pittsburgh, Department of Industrial Environmental Health Sciences (The UPITT Test - The University of Pittsburgh Test Protocol for Measurement of Acute Lethality of Thermal Decomposition Products from Specimens).

The test has a pass/fail criteria. It must not be more toxic than wood, which produces a 50 percent lethality rate at a total mass of 19.7 grams. Upon the receipt of successful test results, the City of New York will grant a Materials and Equipment Acceptance (MEA) number for the designated product.

[Note: International Building Code Chapter 8 Section 8901.1.1, on interior finishes. Exception: Materials having a thickness less than 0.036 inch (0.9mm) applied directly to the surface of walls or ceilings.]

The IBC does not factor in primers and paint applications or high-performance coatings as an integral part of a wall or ceiling system, whether constructed using a light gauge steel stud and drywall composition or masonry wall. Historically, manufacturers have only been required to test the primer and paint product and coatings without the substrate. It is therefore highly uncertain as to the classification of a given system unless the whole assembly is tested.

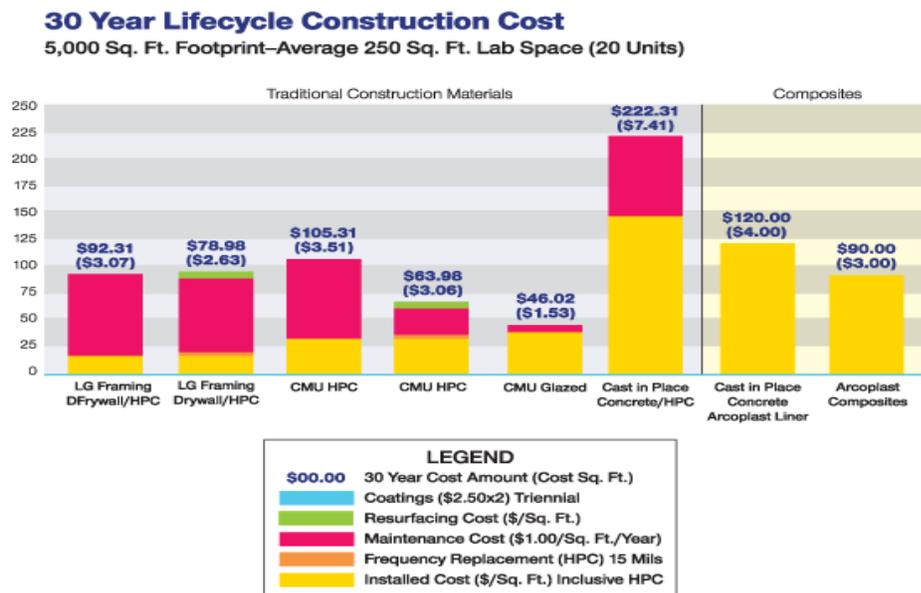
Arcoplast fiberglass reinforced composite panels also comply with the IBC Chapter 8 Section 801.1.3 referring to interior finishes below the design flood elevation to be flood-damage-resistant materials.

Cost Comparisons

The total cost of interior finishes ownership should include a combination of the initial capital costs, including design and installation, as well as all potential maintenance, repair, and replacement costs. In addition, the time and interruptions introduced by any necessary maintenance, repair or replacement should be taken into consideration. Any potential failure could jeopardize the project and its competitive advantage, resulting in a significant loss of time and income for the organization.

Initial Capital Cost

There are considerable differences between the capital costs of interior finishes. The following graphic features the installation costs of various interior finish options, including the costs of both labor and materials and compares the initial capital cost to the 30 Year Lifecycle Cost.



Drywall is one of the least expensive options, but it requires the addition of a high-performance surface coating, introducing a host of variables, thus a high risk of failure to the project.

Stainless steel panels are costly, and challenges are presented by their design inflexibility, gasket-type joints, drabness, and easily damaged surface.

Masonry block is less expensive but is heavy and limited in design flexibility. Surface porosity and mortar joints increase maintenance cost as well as contamination risks.

Specially formulated concretes have extremely high initial capital costs and tremendously long design and installation phases. Because of curing time, it can be nearly one year before surface finishes can be applied.

Arcoplast is not the most expensive, nor the least. However, because of its numerous advantages, it is clearly the best choice and results in the best economic benefits in the long run.

Arcoplast's permanent gel coat finish is an intricate part of the panel itself, so sealants do not have to be applied. Seamless joints prevent potential areas for contamination. The panels and finishing compounds have a beautiful, bright white finish which has an extremely high chemical resistance critical in sanitation and decontamination procedures. Although the gel coat surface may be pounded with a hammer and not show any signs of damage, it is possible to scratch the gel coat surface with a sharp object or chip the edge with a screwdriver during installation. If so, small cracks or chips can be easily repaired on site with gel coat paste.

Arcoplast offers greater design flexibility and a brief installation phase, so business may commence immediately. The panels can be assembled in virtually any fashion. They can perform as cavity-less free-standing partitions, walk-on ceilings composed of light gauge steel members, wall and ceiling liners, load bearing partitions, chase systems, beam covers and bulkheads. It is hard to put a price on the design freedom Arcoplast allows.

Long Term Cost

Arcoplast does not require the addition of high-performance surface coating like drywall and some masonry block. It has its own built in high performance surface finish which never needs to be repainted or re-surfaced, eliminating redundant labor and material expenditures, business interruptions and the risks generated by the restoration and moving equipment in and out of the area.

Arcoplast panels do not need regular buffing or polishing like stainless steel, eliminating redundant expenditures for this practice. And, because Arcoplast's surface cannot be dented or damaged by harsh disinfecting solutions, replacing the panels will not be necessary.

Arcoplast has seamless joints that will never crack or deteriorate, so it will not require repair or replacement of broken tile or failing grout like masonry block. Again, maintenance costs and business interruptions are avoided.

With cast in place concrete, the surface finish is controlled by the substrate's behavior. Long term issues include inadequate structure, building movement and challenging sanitation and decontamination regimens. These are non-issues with Arcoplast, due to its tough, impermeable fiberglass reinforced polymer composite, smooth, non-porous and high gloss gel coat.

Arcoplast systems are easily adapted to future expansions and are designed to outlast the life of the facility. Their maintenance-free characteristics and guaranteed effectiveness provide substantial cost savings throughout their life cycle.

It is impossible to determine exactly how much it would cost to repair or replace a mission critical environment in the event of a failure. However, we do know it would be excessive. The bottom line is failure must be avoided.

Historical Cost Indexes

To understand the economic impact of the fact that Arcoplast panel systems are designed to outlast the life of the facility, we must examine what the replacement cost of a facility might be.

Based on the RS Means Historical Index, average building costs can be converted as follows, with time adjustment using formulas from Historical Cost Indexes:

$$\frac{\text{Index for year A}}{\text{Index for year B}} \times \text{Cost in year B} = \text{Cost in year A}$$

$$\frac{\text{Index for year 1980}}{\text{Index for year 2010}} \times \text{Cost 2010} = \text{Cost 1980}$$

$$\frac{62.9}{183.5} \times 10,000,000.00 = .3427 \times 10,000,000.00 = \$ 3,427,000.00$$

In 1980, the construction cost for the project in this example would have been \$3.427 million. It would cost \$10 million to build the same project today—a 190% inflation rate. Based on this approximate increase of 190%, (assuming the same economic behavior), this project would cost \$29 million to build in 2040. The value of today's vs. tomorrow's building costs should always be kept in mind when planning your current and future projects.

Summary

In the construction of biosafety laboratories, high containment facilities and mission critical environments, true "value engineering" must take the entire life cycle cost into consideration. Yes, the initial design and installation costs are important. However, you must also take the long-term maintenance, repair and replacement costs into consideration when determining total cost.

We have examined the features, benefits, predictability, and reliability of six different interior finishes used in containment facility construction. We have demonstrated that Arcoplast architectural wall and ceiling panel systems are the best choice in terms of design flexibility, installation, and long-term performance. We have shown how these characteristics translate into cost savings and have concluded that the total cost of ownership of Arcoplast systems is comparable if not lower than other interior finish options.

As a bonus, Arcoplast panel systems provide peace of mind. Failure in a high containment facility is dreadful and may result, not only in excessive expenditures, but years of lost productivity. Because Arcoplast is predictable and reliable, you will not need to worry about long term maintenance and replacement costs.



Arcoplast Fiberglass Reinforced Polymer Composite Panel Systems

To learn more about Arcoplast wall and ceiling systems, visit www.arcoplast.com. Or contact Arcoplast at (636) 978-7781.