Division of Technical Resources
Office of Research Facilities
The National Institutes of Health
Vol. 01, No. 58
January 2015

# News to Use

Design Requirements Manual

*The formulae* $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_i U_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ *for building* $\frac{\partial}{\partial x_j}(\rho\overline{U}_i\overline{U}_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U}_i}{\partial x_j}-\rho\overline{u_i'u_j'}\right)+g_i(\rho-\rho_0)$ *state of the art* $\frac{\partial}{\partial x_i}(\rho\overline{U}_i\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{T}}{\partial x_i}-\rho\overline{u_i'h'}\right)$ *biomedical research facilities.*

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Please address questions or comments to: shawm@mail.nih.gov

## Laboratory Plastic Laminate

Plastic laminate is a common finish material for benchtops, shelving and other surfaces in light duty labs. In labs with moderate use of chemicals and infrequent wash-down, plastic laminate can be an economical alternative to epoxy, phenolic resin, stainless steel and other more costly finish options. Plastic laminate is available is in wide range of colors and patterns, and can present an opportunity to add color to a lab. Note that plastic laminate is not allowed in many types of labs, including containment labs and animal facilities. A moisture proof, monolithic material should be used in lieu of plastic laminate at sinks and other wet locations.

### Overview

Plastic laminate is composed of compressed Kraft paper layers, a decorative or colored core layer and a top melamine overlay bonded with resin and sandwiched together to make solid plane sheets (figure 1). The sheets are then adhered with adhesive to a substrate. Particleboard is the most popular substrate used for plastic laminate, though medium-density fiberboard and plywood are also used. The laminate surface provides a thin, lightweight, and simple construction to appear as a seamless monolithic finish for shelving, countertops and other surfaces. Laminate surface performance depends on its grade, its environment and its properties.

**Figure 1**:
Plastic Laminate Construction

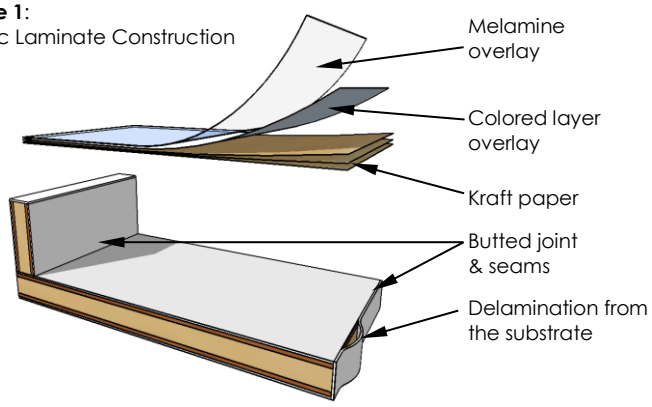


**Figure 2**:
Traditional Plastic Laminate Detailing

Standard laminates are susceptible to scratches, chips, burns, and stains and can warp if exposed to excessive moisture and humidity. High quality, chemical resistant laminates are more resistant to harsh acids, alkalis, corrosive salts, and other destructive and staining substances, and should be used for all laboratory projects. Plastic laminate must be applied to all exposed surfaces, and must be completely sealed.

### Delamination

The most common problem with plastic laminate is delamination from the substrate due to moisture infiltration. Most plastic laminate is installed with exposed butted joints at edges (figure 2), which can provide a pathway for moisture to migrate to the underlying substrate. Because the substrate is wood-based (typically plywood, particle board or fiberboard), moisture will cause the substrate to swell, which will ultimately lead to delamination of the plastic laminate from the substrate. Once delamination occurs (figure 2) the surface is not suitable for laboratory use and must be repaired or replaced.

### Successful Plastic Laminate Installation

To reduce the chance of failure, the use of plastic laminate should be reviewed with laboratory users and facility managers, and only installed in appropriate locations. When used, plastic laminate should be installed on a rigid and stable substrate, and with a minimum of joints.

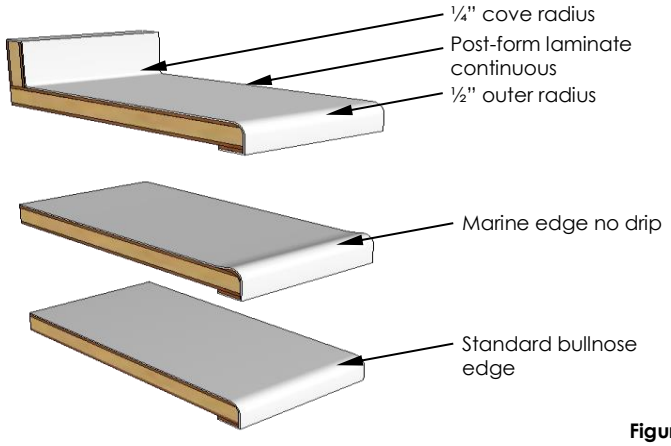


**Figure 3**:
Typical Post-form Laminate Detailing

One way of minimizing joints is to utilize post-formed edges. Post-forming wraps the plastic laminate around inside and outside edges, eliminating butted edges (Figure 3). Post-formed edges provide fewer opportunities for moisture to infiltrate the substrate, and fewer joints to seal. Another advantage is that post-formed benchtops edges can be constructed in a variety of profiles, including bullnose and marine edge.

Although it is not as durable as some of the alternative materials, plastic laminate can provide an economical laboratory finish surface in the appropriate locations if carefully detailed and installed.

Further details on this month's topic are available on the DRM website
http://orf.od.nih.gov/PoliciesAndGuidelines/BiomedicalandAnimalResearchFacilitiesDesignPoliciesandGuidelines/Pages/DesignRequirementsManualPDF.aspx
DRM Chapter 4 Section 4-5 Casework and Equipment

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## Phenolic Resin Panels in Laboratories

The January News to Use provided an overview of plastic laminate, and its use in light-duty laboratory applications. Due to laminate's susceptibility to delamination a more durable material is often required. One of these materials is phenolic resin.

### Advantages of Phenolic Resin Panels

Phenolic resin panels are a more durable and moisture resistant alternative to plastic laminate. Phenolic resin panels and plastic laminate panels are similar in basic composition, consisting of a thin plastic-based surface sheet laminated to a rigid substrate. Phenolic resin panels, however, have a number of advantages over plastic laminate panels, including:

- Impervious core. Unlike the substrate of plastic laminate panels (typically plywood, particle board or fiberboard) phenolic resin panels utilize a cellulose fiber-reinforced phenolic resin core that is monolithic and impervious to water.
- Factory lamination. Plastic laminate is typically laminated to the substrate in a fabrication shop or in the field, using contact adhesive. Phenolic resin is laminated in the factory using thermosetting resins, heat and pressure, which results in a very durable bond which is resistant to moisture infiltration and delamination.

Phenolic resin panels were developed about 30 years ago, and have a history of use in a wide range of applications, including furniture, casework and exterior building cladding. Laboratory-specific phenolic resin panels are a more recent development, and are formulated to be chemical and heat resistant. The chemical and heat resistant properties of laboratory-specific phenolic resin panels compare favorably to epoxy and other benchtop materials for most laboratory applications.

### Uses and Versatility

Phenolic resin panels are available in thicknesses ranging from ¼" to 1". Benchtops and shelves are generally ¾" or 1" thick. Thinner panels can be used or ancillary items including pegboards, utility enclosures, divider panels and back and side splashes. Panels can also be used for casework construction, tabletops, lockers and other uses in the lab.

Phenolic resin panels are available in lengths up to 10' and widths up to 6' wide, so joints are required in long runs of benchtops and shelving. Joints are typically mechanically fastened edge joints using biscuits or splines, and adhered with epoxy or polyurethane adhesive. Phenolic resin panels can be worked with standard carbide tipped carpentry tools, and can be secured with wood screws Panel cores are impervious to moisture, so core edges do not need special treatment and can be left exposed. Exposed cores allow for field modifications and the installation of under mount sinks. Phenolic resin sinks are not available, so epoxy or stainless steel sinks are usually used.

Laboratory-grade phenolic resin panels are available in a limited choice of surface laminate colors, including black, white and a range of grays. White and grays are increasingly popular as way of introducing visually appealing hues and light, reflective surfaces into the lab. Non-laboratory grade panels, which may be appropriate for uses other than benchtops, are available in a wide range of colors and patterns including wood grains.

Panel cores are black, so unfinished edges will contrast with any other color surface. Exposed core edges can be concealed with applied banding that match the surface color. On benchtop edges, 'L' shaped banding can be applied to conceal the core and provide a marine edge (Figure 1).

### Sustainability

Phenolic resin panels are not recyclable, and have limited recycled content. Up to 70% of the volume of the core material is derived from renewable resources (cellulose fibers from sustainable forests). Greenguard® certified low VOC phenolic resin panels are available.

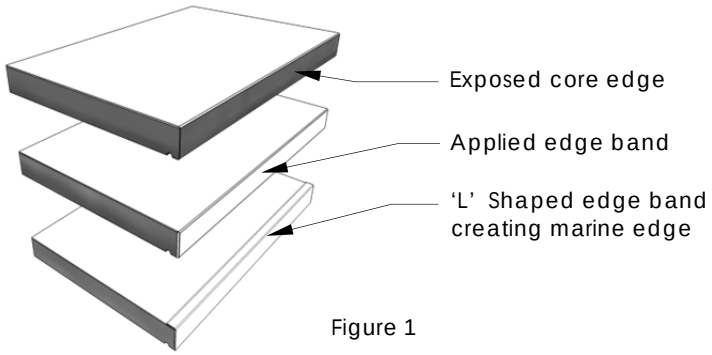


Figure 1

Although it is not a monolithic material like epoxy, the impervious core manufacturing methods give phenolic resin panels some of the same characteristics and properties. Phenolic resin panels should be considered for use in areas not appropriate for plastic laminate panels, but where the durability of epoxy is not required.

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DRM Chapter 4 Section 4-5 Casework and Equipment

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# Epoxy Resin Benchtops

The last two issues of News to Use provided overviews of lab grade plastic laminate and phenolic resin as options for laboratory benchtops. This month the topic is the most commonly used benchtop surfaces, epoxy resin.

Epoxy resin is the successor of traditional soapstone benchtops, and has been the workhorse material in chemical-intensive laboratories for many years. Epoxy resin is an oven-cured mixture of epoxy resin, silica, a hardener and filler materials.

**Characteristics:**
The standard epoxy resin sheet used for benchtops is 1" thick, but ¾" and 1 ¼" are also available. The largest available sheets are 72" x 96", so joints are necessary in long runs of benchtop. Joints are butt-type, with metal splines and epoxy adhesive. Leading edges can either be beveled 1/8" or radiused 3/16". An applied or integral marine edge is available, as are drip grooves and other profiles.

Because epoxy resin is a monolithic material under mount sinks can be used. Sinks can be epoxy resin, sealed to the benchtop with epoxy adhesive to create an integral assembly, stainless steel or other materials. Backsplashes, reagent shelves and bottle racks can be fabricated from epoxy resin material.

Because it is monolithic and does not absorb liquids, epoxy resin can be easily cleaned. Light surface abrasions can be repaired with commercially available cleaning products. For deeper cuts or stains an orbital sander with 120 grit or finer wet/dry sand paper can be used.

Black is the standard color, but epoxy resin countertops are also available in several other colors, including grey, blue, tan and white. Color choices other than black will incur cost increases anywhere from 15% to 45%.

**Advantages:**
Epoxy resin has a number of properties which makes it a good choice for benchtops in most laboratory applications:

- **Chemical resistance:** Epoxy resin is non-absorbent, stain resistant and is highly resistant to most commonly used laboratory acids, solvents and other chemicals. It is also monolithic, so scratches do not reduce its chemical resistance.
- **Durability:** Epoxy resin is hard and dense, so it is durable and abrasion resistant. Because it is monolithic, it does not delaminate.
- **Heat and flame resistance:** Epoxy resin is non-flammable and resistant to high temperatures.
- **Versatility:** Epoxy resin is available in molded shapes including marine edges, integral backsplashes, sinks, pegboards and other laboratory accessories (figure 1).

**Other Considerations:**
In recent years alternate materials, including phenolic resin and chemical resistant plastic laminate, have become available as alternatives to epoxy resin. These materials approach the chemical resistance of epoxy resin, and have some distinct advantages over epoxy resin which should be considered during the selection process:

- **Weight:** At about 12 lb./sq. ft. epoxy resin is substantially heavier than alternate materials. Weight can be an advantage for increasing the stability and vibration characterizes of benches and furniture, but can be a disadvantage, especially for mobile and adjustable benches. Weight also increases fabrication, shipping and installation costs.
- **Fabrication:** Because of epoxy resin's density and harness, it must be cut with diamond-tipped blades and the use of water-cooling of blades is recommended. Most epoxy resin fabrication must be done in a fabrication shop, unlike other materials which can be modified and fitted on site. This results in higher fabrication costs and makes future modifications more difficult.
- **Cost:** The material cost of epoxy is more than alternates. Epoxy resin is also more costly to fabricate ship and install.
- **Resistance to low temperature:** Although it resistant to high temperatures, epoxy resin is susceptible to damage from thermal shock from low temperatures, and may crack if exposed to liquid nitrogen or other cryogens. This is an especially problematic with epoxy resin sinks, when dry ice is placed in the sink to sublimate, resulting in cracking.

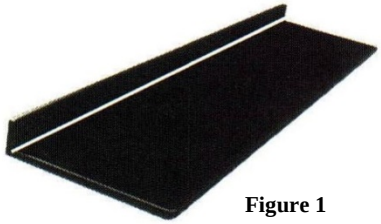

**Figure 1**
Epoxy resin benchtop with integral backsplash

**Sustainability:**
This material has limited value in obtaining credit for use of sustainable products. Recycled silica or filler can be used in the manufacturing process, but epoxy resin is generally not recycled or recyclable.

Epoxy resin is a very durable, stable, and long lasting laboratory countertop material. Even though this material has a higher first cost, its durability, chemical and heat resistance can outperform less expensive materials in life cycle cost. When old labs are renovated, it is often the epoxy resin countertop which has retained its appearance and usefulness over time better than any other finish material in the space.

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# NIH Design Requirements Manual 2015 Update

The National Institutes of Health (NIH) Design Requirements Manual (DRM) establishes policy, design requirements, standards and technical criteria for use in planning, programming, and designing NIH owned, leased, operated, and funded buildings and facilities. The DRM is the only detailed design requirements and guidance manual for biomedical research and animal research facilities in the U.S. The information compiled within the 2015 DRM is the result of technical studies that have set numerous national and international standards, lessons learned and ever advancing architectural and engineering technologies used in the design and construction of research facilities. The Division of Technical Resources (DTR) is responsible for maintaining and updating the DRM.

In order to ensure the most current, relevant, and comprehensive manual, DTR continuously researches and tests state-of-the-art and innovative technologies that may be applicable to biomedical research facilities. DTR has gathered data from these studies as well as from numerous years of specialized experience and an accumulation of lessons-learned from the design and construction of NIH's unique biomedical research and animal facilities. This has led to data-driven decision making and best practices for the design and construction of NIH's facilities. The results of these studies are incorporated into the 2015 DRM and new information will be added as it becomes available.

The 2015 DRM edition constitutes a major restructuring and reorganization of the 2008 edition, with the addition of a vast amount of new and updated information for architects & engineers (A/E) and stakeholders to use in the facility design process.

**The DRM Update Process:**

In order to provide guidance and standards which represent the best practices in biomedical research facility design, DTR assembled over 120 professionals from industry, academia, as well as government consisting of lab designers, architects, engineers, researchers, veterinarians, maintenance staff, biosafety specialists, and others. These professionals were divided into nine technical committees with one Executive Steering Committee to advise and arbitrate. The nine technical committees were divided as follows: Architecture, Mechanical, Electrical, Plumbing, Structural, Civil, Biosafety, High Containment, and Animal. Each committee was comprised of professionals with expertise in a variety of disciplines and unique insights into the complicated design, construction, and functional issues involved in biomedical research facilities.

Each committee reviewed the initial draft for the update to the 2008 DRM and provided comments during a series of weekly meetings. DTR then incorporated the committee comments and insights into a second draft of the DRM update. After thorough review by the DTR staff as well as technical editors and outside independent experts, the second draft was released again to the committees for another round of comments and 2nd Draft of the document. DTR technical staff evaluated each comment and modified the DRM as appropriate.

The 2015 DRM is now being reassembled and reviewed internally before it once again is released for a wider public review of over 200 experts and professionals. It is DTR's expectation that due to this extensive and thorough process the 2015 DRM will be the premier document in laboratory design guidance in the country.

**Significant Changes from the 2008 DRM:**

The 2015 Design Requirements Manual has undergone major changes from the 2008 edition. Every chapter and appendix has been updated to align with the latest in research laboratory design.

Some of the notable additions / changes to the 2015 edition are as follows:

- **Design, Format, & Links:** New look & two column format to ease reading. Additionally, links have been added to ease the transition between references within the document.
- **Rationales:** Additional text further elaborates and clarifies difficult technical issues related to facility design; providing the intent of requirements and giving better guidance to A/E's who utilize the document.
- **Expanded Sustainability Requirements:** In order to meet new and changing sustainability goals, the DRM now provides further guidance on the design of facilities with smaller carbon footprints and reduced energy goals.
- **Graphics:** The 2015 DRM contains significantly more diagrams and graphics to help illustrate complex planning & design concepts.
- **Specialty Labs:** As science and research is ever changing specialty labs are becoming more common. The 2015 DRM will include information on a variety of specialty lab facilities, highlighting important technical issues which the A/E's need to be aware of during design.
- **New Appendices & Reference Documents:** New and updated appendices will provide more concise and valuable direction to A/E's. Some new and updated appendices include: A/E Submission Checklist, Room Data Sheets, Sample Equipment Schedule, among others.

After a long and meticulous process the 2015 DRM will be published within a few months. It is through the efforts of many dedicated individuals that the 2015 DRM has become a reality. DTR extends our sincerest thanks to all of the people who helped improve and refine the 2015 NIH Design Requirements Manual.

Further details on this month's topic are available on the DRM website
http://orf.od.nih.gov/PoliciesAndGuidelines/BiomedicalandAnimalResearchFacilitiesDesignPoliciesandGuidelines/Pages/DesignRequirementsManualPDF.aspx

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# Project Close-out

The close-out of a project is a major milestone, and the culmination of the design and construction process. All parties are usually anxious for completion of close-out: the Architect/Engineer (A/E) and contractor can receive final payment, and the Project Officer (PO) can move on to other projects, and the Institute or Center (I/C) can plan occupancy. The objectives of project close-out should be defined, however, so that the process can go smoothly and successfully, without unforeseen problems or delays.

## Definitions

The definition and process of close-out for a particular project will depend on the specific contracts and contract documents governing that project. The following are some widely recognized industry close-out terms:

### Punch List

The punch list is a list, developed by the contractor and reviewed by the A/E and PO, of all items on a construction project that must be finished to fulfill the construction contract. When complete, a punch list is a set of mutually agreed items necessary for the project to attain final completion. If the items on the punch list are relatively minor the punch list can be a trigger for substantial completion and beneficial occupancy.

### Substantial Completion

Substantial completion is the point where the project is completed to the point where it can be functional for its intended use. Typically substantial occupancy is attained when the punch list contains only minor items and all systems are operational.

### Beneficial Occupancy

Beneficial Occupancy is the full or partial use of the facility by the I/C for its intended use prior to Final Completion. For beneficial occupancy to occur, remaining punch list items should be minor, so that remaining contractor activities will not be a nuisance or hazard to occupants. Before beneficial occupancy occurs, a formal agreement with the contractor should be developed to define the obligations of the contractor and occupants relative to maintenance, utilities, security and other responsibilities. A drawback to beneficial occupancy is that damage or loss resulting from occupancy is not the responsibility of the contractor, so conditions prior to beneficial occupancy should be carefully and thoroughly documented. The PO, the Division of the Fire Marshal (DOFM) and other Authorities having Jurisdiction (AHJ) must approve all space for occupancy. In addition, Division of Health and Safety (DOHS) certification is required for occupancy of all containment laboratories.

### Final Completion

Final completion is that date that all punch list items are complete, the terms of the construction contract are complete, and the project is accepted. Final completion is the traditional date for the contractor to submit for final payment.

## Close-out Activities

Between the Punch List and Final Completion a number of activities must be scheduled and completed to ensure that the close-out procedures go smoothly and without delay to ensure that the transition from contractor management to I/C management and occupancy goes smoothly. These include:

### Operations and Maintenance (O&M) Training

Substantial completion is often the time when responsibility for operations and maintenance transfers from the contractor to permanent O&M staff. It is important to schedule training of the permanent operations and maintenance staff of all systems and the transfer of O&M manuals.

### As-built Drawings and Project Records

All documentation required to record the construction process, document the as-built construction conditions and to manage the facility. These may include CAD drawings or BIM models, testing reports, construction reports and photographs, RFIs, change orders and other project documentation. Documentation should be neatly organized and indexed, in paper and/or electronic format, as required in the contract documents.

### Testing and Balancing of Systems

All systems are inspected, tested and adjusted to ensure that operation, performance, energy efficiency and occupant comfort meet design criteria. This may be part of a more comprehensive commissioning procedure. Systems that are utilized on a seasonal basis must be tested and used through a complete annual load cycle (i.e. cooling systems must be tested, even in the winter).

### Warranties

Substantial completion is the traditional start date for warranties associated with the project. Complete warranty paperwork for all systems should be indexed and organized in a binder for future reference. Information should include warranty terms, conditions and durations, as well as the names and contact information for warranty holders.

### Delivery of Attic Stock

Attic stock must be delivered and stored in a location specified in the contract documents or as specified by the PO. Attic stock should be in unopened containers, labeled and neatly organized.

### Installation of Government Furnished, Contractor Installed (GFCI) Equipment

The delivery of GFCI equipment should be coordinated with the contractor and scheduled prior to final completion. If equipment arrives on-site too early it may be subject to damage, and if it arrives too late the contractor may have demobilized.

### Contractor Demobilization

The contractor must remove trailers, temporary fencing and barriers, and all other construction-related items not wanted by the Government, and the project area must be cleaned and restored.

## Summary

It is important for close-out procedures and schedule to be understood and acknowledged by all parties. Close-out requirements, procedures and responsibilities should be included in the contract documentation, and a schedule of activities covered in a close-out conference.

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DRM Chapter 1 Section 13 Acceptance, Activation and Occupancy

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# Operable Windows

The potential benefits and increased use of operable windows in institutional buildings has raised questions regarding the Design Requirements Manual (DRM) prohibition of their use in laboratories and animal research facilities. The purpose of this article is to provide a brief overview of the issue and to provide rationale for the prohibition.

In recent years operable windows have become increasingly common in many types of buildings, including a number of prominent high-performance buildings. Operable windows have a number of benefits and their use in office and other non-research space should be assessed in consideration with the building's geographic location, function, budget, sustainability goals and other factors. Operable windows, however, are functionally incompatible with NIH laboratories and animal facilities.

## Benefits and Advantages

Operable windows provide natural ventilation which has a number of potential benefits, including:

**Reduced utility costs**. Natural ventilation allows the introduction of warm and cool air to the interior of building during favorable outside temperature and humidity conditions.

**Increased occupant comfort**. Natural ventilation provides air movement which, at moderate velocities, make a space comfortable under a wider temperature range than still air.

**Psychological benefits**. Many people prefer 'fresh' air and the auditory and olfactory connection with the outside environment. Many people also prefer to be able to control their environment by being able to open or close windows.

**Air quality**. Outside air has less CO2, VOCs and other undesirable contaminants associated with product outgassing in addition to the contribution of the occupant load.

## Incompatibility with Research Space

Despite the advantages, natural ventilation causes a number of conditions which are incompatible with the function of research laboratories and animal facilities. These facilities operate under highly controlled environmental parameters which cannot be maintained with operable windows, thus the prohibition in the DRM.

These include:

**Temperature and humidity control**. Research facilities are designed to operate within a limited temperature and humidity range due to the sensitive nature of the processes performed and the equipment used. Operable windows can cause temperature and humidity swings in excess of those experienced by a space with fixed windows. High humidity can cause condensation. Temperature and humidity variations can negatively impact precision equipment.

**Air movement**. Unpredictable air movement around fume hoods, biological safety cabinets and similar devices can negatively impact their performance compromising the safety of personnel.

**Pressurization and containment.** Laboratories are generally negatively pressurized relative to corridors and public spaces to control potential airborne hazards and provide containment. Operable windows create fluctuating air pressure, making control and containment virtually impossible.

## Other Factors to Consider

In addition to building type and function, geographic location is a key determinant to the practicality of operable windows. In most geographic regions the climate requires that a building utilizes operable windows for a portion of the year, and mechanical heating and cooling the rest. The climatic design data found in ASHRAE Fundamentals, unique for each city, provides information that can assist in determining the number of days that operable windows can be comfortably used, considering historic temperature and humidity data. Other considerations include topography, prevalence of storms, high pollen and particulates and other factors that could limit usage. The benefits of operable windows have to be weighed against the costs and the number of days that they will be used.

Other factors to consider are:

**Cost**. Operable windows have a higher first cost than non-operable windows.

**Air quality**. HVAC systems typically include filters, which reduce the particulates in the air. Without this higher levels of pollen, dust and other contaminants can enter and accumulate inside the building.

**Increased HVAC system burden**. If windows are inadvertently left open, the building HVAC systems can experience an unduly high heating or cooling loads and higher relative humidity which the HVAC system is required to control.

## Conclusion

Operable windows have a number of benefits in office and other non-research space, and their use in a particular project should be assessed relative to a number of factors, including geography; sustainability goals and budget. Operable windows, however, create uncontrolled interior environments, including temperature, humidity and pressurization fluctuations, which makes their use incompatible with laboratories and animal research buildings.

Further details on this month's topic are available on the DRM website:
Design Requirements Manual
DRM Chapter 4 Section 4 Exterior Architectural Elements

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# Reliability of Electrical Systems

Reliable electrical power system requires that designers minimize single point of failures in the system. A single point of failure is a single point in the electrical power system beyond which the electrical power system is down from the failed piece of equipment or power supply. Adding redundancies to the electrical power system is usually an effective method to minimize single point failures. This may involve addition of redundant power sources, electrical distribution equipment, cable routing, etc. Ensuring reliable electrical power system for the cutting edge research facilities at the National Institutes of Health (NIH) requires careful consideration of electrical reliability measures, eliminating single point of failures with reasonable cost benefit returns.

In addition to reliability requirements, electrical system at the NIH facilities must be scalable to facilitate future expansions, easy to operate and maintain for the long period of continuous operations since many of the facilities operate twenty four hours a day. As a result, simply adding redundancies or selecting topology without due considerations of all operational requirements may not meet the NIH requirements.

First, designer must consult with all stakeholders to determine the value of uninterrupted operations. This varies from one laboratory to another at the NIH campus depending on the types of research activities conducted in the laboratory. As an example, patient/animal research areas will require highly reliable electrical power systems compared to an administrative building or segment of building with similar functionality. Designers must establish a common ground about the reliability with all of the stakeholders prior to selecting topology of electrical power distribution system and measures to eliminate single point of failures.

Second, designers must establish cost of the various alternate solutions with increasing level of reliabilities so that stakeholders can select an appropriate electrical system that meets the reliability requirements with least negative impact on budget. Reliability calculation for the proposed systems must follow IEEE standard 493 (IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems). In addition, reliability calculation must include actual historical outage data of Potomac Electric Power Company (PEPCO, the local electric power service provider).

Finally, designers must:

- Choose a network architecture that strikes the right balance between risk mitigation and return on investment (ROI)
- Select reliable equipment configured for each process and load
- Implement an appropriate maintenance policy with corrective, preventive, and predictive measures
- Install a power monitoring and control system with the following features, to help operators make the right decisions and take the appropriate corrective actions:
  - Real-time monitoring of the entire electrical network
  - Alarming, data logging, event tracking, fault analysis, and root cause analysis

Many facilities at the NIH campus have been operating for 30 years or more with continuous need for modification. Therefore, new electrical systems must be scalable as well as compatible with the existing systems to integrate seamlessly with the existing systems. New electrical power system should also meet stringent criteria for reliability including elimination of single point of failures, operability, and maintainability to ensure that designed system will operate for entire life of the building.

Further details on this month's topic are available on the DRM website:
Design Requirements Manual
DRM Chapter 10, Section 3 and Section 9

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# News to Use

Design Requirements Manual

The formulae $\frac{\partial \rho U_i}{\partial t}+\frac{\partial}{\partial x_j}(\rho U_i U_j)=-\frac{\partial P}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial U_i}{\partial x_j}\right)+g_i(\rho-\rho_0)$ for building $\frac{\partial}{\partial x_j}(\rho\overline{U_i}\,\overline{U_j})=-\frac{\partial \bar{P}}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\frac{\partial \overline{U_i}}{\partial x_j}-\rho\overline{u_i'u_j'}\right)+g_i(\rho-\rho_0)$ state of the art $\frac{\partial}{\partial x_i}(\rho\overline{U_i}\overline{H})=\frac{\partial}{\partial x_i}\left(\lambda\frac{\partial \overline{T}}{\partial x_i}-\rho\overline{u_i'h'}\right)$ biomedical research facilities.

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# Cooling Coil and Drain Pan Requirements for Air Handling Units

For NIH Facilities, cooling shall be provided by the use of chilled water/hydronic systems. Since chilled water is normally produced and delivered more efficiently, the use of air-cooled, self-contained refrigeration systems for building cooling coils in air handling units shall be avoided per the NIH Design Requirements Manual (DRM), unless chilled water is not available. The major focuses of this article are to highlight proper handling of condensate drain from chilled water cooling coil, improve coil performance, reduce moisture carryover, minimize potential of mold growth, reduce potential for corrosion, premature replacement of downstream components and facilitate coil maintenance and replacement.

Cooling coils on air handlers serving laboratories and animal facilities are designed to remove significant amount of latent heat loads from the outside air, which is 100% of total air, brought into the units. As a result, significant amount of moisture accumulates on the coil surface. This may lead to numerous failures unless addressed properly. Maintaining the proper air face velocity through the coil and ensuring proper drainage are essential to prevent moisture carryover. The cooling coil's air face velocity shall be sized for a nominal air face velocity not to exceed 2.0 m/s (400 fpm) for the present design conditions and 2.5 m/s (480 fpm) for the future growth capacity.

On high volume air handling units, the size of cooling coil may exceed the maximum individual coil size of 3.0 m (10 ft.) long by 0.91 m (3 ft.) high, and require that, multiple coils would need to be provided. Since the maximum single coil height is 0.91 m (3 ft.), the additional coils must be provided with a dedicated condensate drain pan and chilled water piping connections. Multiple coils shall be valved separately so that, if any individual coil fails or requires service, it can be isolated and drained as needed while the remaining coil(s) remain in operation. Coils shall be installed to allow the removal of individual coils without disturbing pipe headers or anything else that would prevent the remaining coils from operating. Coils shall be removable without major rigging. The return header for multiple-stacked coils shall be piped in a reverse return configuration to assist with the balancing of the water flow. Strainers shall be provided on the feed line for each coil bank. Control and balancing valves shall be installed on the return line. Each coil shall be provided with a balancing valve with integral memory stop. Combination balancing/shutoff, devices are not acceptable per the DRM.

On multiple or stacked coils, each coil or coil bank shall be provided with its own drain pan, wherein the upper coils shall be provided with a drain pan, also known as "intermediate drain pan". The drain pans shall be designed with the following criteria:

- Drain pans shall extend a minimum of 12-in downstream of the cooling coils. (ASHRAE 62t recommends one half of the installed vertical dimension of the coil or assembly.)
- The drain pan shall be stainless steel with a positive slope to a bottom drain connection. (ASHRAE 62t recommends that the slope shall be of at least 10 mm per meter (1/8 in. per foot) from the horizontal toward the drain outlet or shall be otherwise designed to ensure that water drains freely from the pan whether the fan is on or off.)
- The bottom pan drain shall extend a minimum of 18 inch downstream of cooling coils and shall be properly trapped and static pressure conditions that accounts for dirty filter(s) shall be used to calculate the trap height.

Other recommendations to maintain the optimum performance of the cooling coil while properly handling the condensate drainage are as follows:

- Ensure that the designed airflow quantity of outside air is adequately maintained to prevent excessive airflow and associated moisture brought onto the coil.
- When sizing the coil, consider the potential increase of internal latent load during the cooling coil design phase.
- Provide a plenum section downstream of the coil with sufficient distance to capture all the moisture before it reaches the next AHU compartment.
- The cooling coil shall be designed for maximum of 8 rows deep and 10 fins per inch to allow easy cleaning of coils. Deeper coils and denser fins clog hinder easy cleaning of coils.
- Cooling coil sections shall have access doors to permit inspections and maintenance.
- Cooling coils shall be arranged in a draw through configuration within the air handler to minimize moisture carryover.
- Condensate drain traps and associated piping need to be kept clean and free of obstructions.
- Moisture eliminators may be considered where carryover presents a problem. However, eliminators shall not impede service access for cleaning of the coil surface.
- Condensate drain traps must have proper tap depth, based upon maximum static pressure at design airflow with fully loaded air filters. Associated piping should be properly sized and kept clean and free of obstructions.
- Routine replacement of air filters as needed.

**In summary,** moisture condensation is the result of the cooling and dehumidification processes within the coil. Having a well-designed and properly maintained cooling coil can prevent the negative effects of airborne moisture or condensate blow off on to the downstream components. Ill effects from mold within the HVAC system and costs associated with its remediation can be significant. Having well-designed and maintained air handling units, including associated condensate management can minimize the potential for moisture carry-over and associated damage and costs.

Further details on this month's topic are available on the DRM website:
Design Requirements Manual
DRM Chapter 6 Section 2 Air Handling Systems

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Design Requirements Manual

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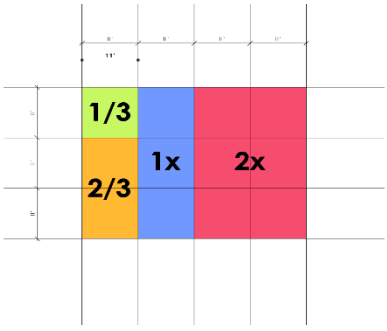
# Improving Design Using 3D Visualization

Excellence in design is a primary goal for all NIH design and construction projects. A commitment to quality by the design and management team is necessary to achieve this goal. Quality architectural and interior design can have a direct impact on improving the facility operating efficiency, attractiveness, life cycle economics, and ultimately, the productivity of the facility users.

Design excellence does not have to add to project costs, but does require a balanced approach to design which optimizes the functionality, aesthetics, quality and maintainability of facilities. One important tool for achieving design excellence is utilizing the power of 3D visualization during the design process.

With the progression of digital design, including advanced Computer Aided Design (CAD) and Building Information Modeling (BIM) there are greater opportunities to integrate 3D visualization into the design and construction process. 3D visualization is accessible via a host of software packages, and from the web and mobile handheld devices. As a design tool 3D visualization is now as common as a designer's sketchbook. It can be used for every day planning and design decisions and is no longer limited to grand presentations.

***Figure 1: 2D diagram of lab module concept***



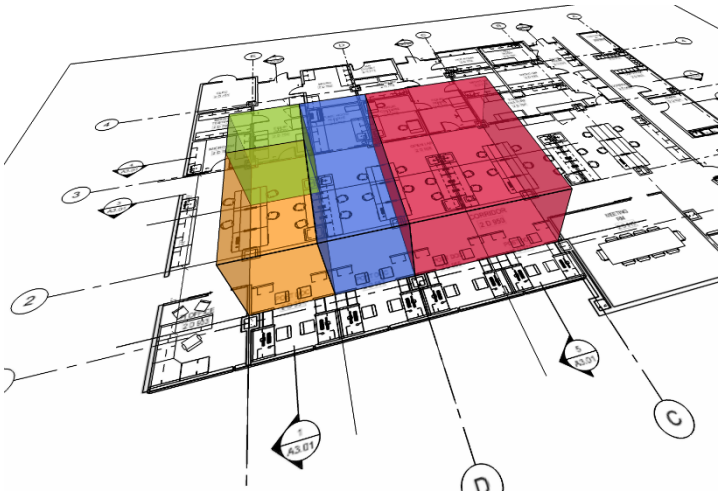

**Design Development Communication**
3D visualization can be used in many ways throughout the design process, including:

**Conveying Information** Scientists and other facility users are not trained in the reading and interpretation of 2D diagrams and plans. 3D images are easier for them to conceptualize and understand, and when an unbuilt space is understood more clearly the resulting discussion, comments and approvals are more meaningful.

**Relationships** 3D visualization is a useful tool for both facility users and design professionals to explore spatial adjacencies and relationships which may not be as readily apparent in 2D drawings. This is especially important with complex facilities with integrated systems and components.

**Volumetric Understanding** Building components, spaces, equipment and other volumetric elements are more easily understood in the vertical axis, which is not easily conveyed in 2D diagrams and plans.

***Figure 2: 3D visualization of lab module concept***



**Level of Detail for 3D models**
The 3D Model can be presented in an array of design levels and technical exactness. Simple volumetric line drawings convey geometry and scale. Greater resolution can show additional levels of detail up to photo-realistic representation. The highest level of detail is not always productive or useful and the appropriate level of representation should be used:

**Basic:** Simple massing models communicate the general organization and configuration of a space or process.

**Intermediate:** Images with a level of detail that may include hardware, equipment, furniture, people (for scale) and other items that convey the use and function of a space.

**Advanced:** Rendered images or walkthroughs with possible real world likenesses, colors, dimensions or shadow illustrate how a space will actual look.

**Summary**
The capabilities of advanced CAD, BIM and other programs should be used to develop 3D visualization tools which can increase understanding and promote dialogue with the goal of improving the level of design.

Further details on this month's topic are available on the DRM website:
**Design Requirements Manual**
DRM Chapter 4, Section 1

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# Vinyl Composition Tile

Vinyl Composition Tile (VCT) has been a reliable flooring material in NIH laboratories for decades, with a good record of durability. Although new products are available VCT is still a good choice for many laboratory applications.

VCT is composed of vinyl (polyvinyl chloride) binder mixed with a filler; the binder gives the tile strength and flexibility and the filler gives the tile color and volume. VCT installed prior to the mid-1980s is typically 9" x 9" squares, and may contain asbestos as a filler. Old VCT, as well as mastic, should be treated as a potentially hazardous material. Newer 12" x 12" VCT generally does not contain asbestos, but its mastic may contain asbestos, so should be treated with caution. The Division of Environmental Protection should be contacted whenever a potentially hazardous material is encountered.

Most of the volume of VCT is filler (usually limestone) which extends though the thickness. The resulting tile is monolithic, which allows shallow scratches and abrasions to be buffed out. The quality of VCT is dependent, in part, on its vinyl content. Higher vinyl content tiles are usually harder, more durable and more flexible.

Specialty VCT is available with a number of properties to address laboratory requirements, including nonslip, antimicrobial, non-conductive and static dissipative tiles.

Before VCT is specified for a project, a number of performance issues should be considered:

**Water Resistance:** Although VCT is water resistant, it is porous and can swell and delaminate from the floor if saturated by water. To increase performance in damp environments VCT must be installed with tight joints and have regular sealant application. VCT is not recommended in rooms subject to very high humidity, repeated wash down or other wet conditions.

**Joints:** VCT tiles are installed with open joints, which can be very tight if installed by a skilled installer. Even very tight joints are difficult to clean, however, so VCT floors are unacceptable in containment labs, clinical applications and rooms requiring clean or aseptic conditions. VCT tiles are installed with an applied vinyl or rubber base, which introduces another joint around the room perimeter.

**Testing:** VCT is available from a number of manufacturers, and produced with a range of formulations, which result in different physical properties. It is recommended that the product data sheets be reviewed to ensure that the specified product matches the requirements of the lab.

**ASTM F-1700,** Standard Specification for Solid Vinyl Floor Tiles. This standard provides dimensional and performance criteria. Minimum requirements include binder content, dimensional tolerance, residual indentation, flexibility, resistance to chemicals and resistance to heat and light.

**ASTM F-925,** Test Method for Resistance to Chemicals of Resilient Flooring. This standard tests surface deterioration when exposed to a number of common chemicals.

**ASTM F-1265,** Test Method for Resistance to Impact for Resilient Floor Tile. This standard tests the reliance of a floor tile to impacts.

**ASTM F-1304,** Test Method for Deflection of Resilient Floor Tile. This standard tests the ability of a floor tile to bend and conform to an uneven surface without cracking or breaking.

**Patterns:** VCT is installed as individual tiles and is available in a wide range of colors, so there are opportunities for multi-colored patterned installations at very low cost premiums. Tiles can be cut, though complex shapes should be avoided. Damaged tiles can be easily replaced.

**Workmanship:** VCT tiles have very tight dimensional tolerances, allowing flooring to be installed with hairline joints. The quality of the installation, however, is dependent on the skill of the installer

**Sustainability:** The manufacture of polyvinyl chloride used in VCT is associated with the release of environmentally hazardous chemicals. More environmentally-friendly alternatives, including rubber and linoleum, should be considered on a case-by-case basis, based on the function and use of the lab and the properties of the flooring. When VCT is used, manufacturer's recycling programs and low volatile organic compound (VOC) tiles and mastics should be used to reduce environmental impact.

**Cost:** VCT is generally among the lowest-cost laboratory floor options.

**Maintenance:** VCT floors must be periodically stripped and sealed. Low VOC maintenance products are available.

**Conclusion:** Although not appropriate for all conditions and not a sustainable option, VCT is a durable product which has a long history of service. VCT should be considered as an economical option for many laboratory projects.

Further details on this month's topic are available on the DRM website:
Design Requirements Manual
DRM Chapter 4, Section 4 Interior Finishes

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# News to Use

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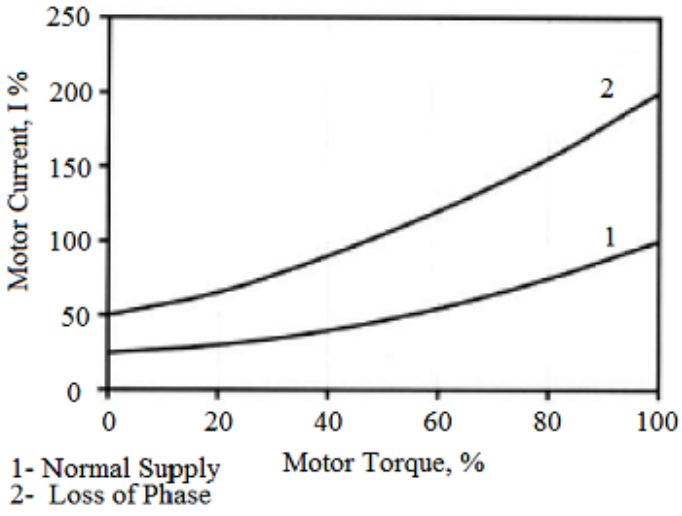
# Single Phase Protection

The single phase condition occurs when one of the phase wires in three phase systems doesn't supply power to the load. This usually happens due to blown fuse, loose connection, defective circuit breaker and line to ground fault not cleared or detected. In a three phase motor, loss of a phase while motor is running will result in an increased current flow in the operating phases since motor will continue to run. Similarly, loss of a phase at the primary side of the three phase transformer will result in an increased current flow as well as unbalanced voltage at the secondary. Protection devices sized at the rated full load current flow may not detect loss of a phase in a lightly loaded system. Engineers must evaluate system operating conditions to specify proper single phase protection system.

**Single Phase Operation of Motor:** Loss of a phase can occur during both startup and running conditions. If a three phase motor is started with one phase wire open, motor will not start as the pulsating current will not create enough starting torque for the motor to start. If the motor loses a phase while running, speed of the motor will decrease and current supply increase sharply. Figure below shows motor current flow for different load conditions:

Figure 1. Torque vs. Current



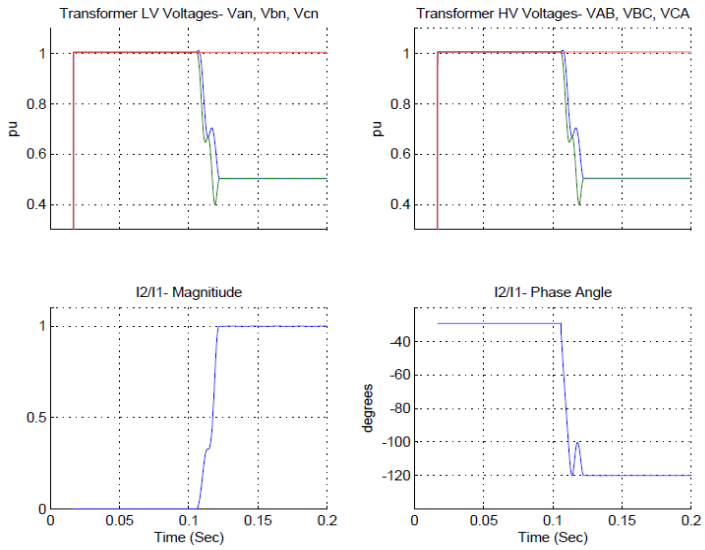

Under full load conditions, motor overcurrent protection will protect the motor since current flow in the operating phase far exceeds full load current, preventing possible motor burnout.

As seen from the graph above, under small load conditions, motor current is smaller than the rated full load current. Therefore, overload protection based on full load operation may not protect the lightly loaded motor.

Further details on this month's topic are available on the DRM website:
Design Requirements Manual
DRM Chapter 10, Section 3 Normal Power

**Single Phase Operation of Transformer ($\nabla - Yg$):** Loss of a phase at the primary side of the three phase transformer will result in both current and voltage unbalance at both primary and secondary side of the transformer. Figures below shows both primary and secondary voltages, current for loss of phase in a three phase transformer with delta primary and Y grounded secondary:

Figure 2. Voltage/Current – Three Phase Transformer




As stated above, voltage unbalance can have deleterious effects on three phase motors. Therefore, single phase protection is usually required to protect electrical systems from permanent damage of equipment, fire hazards, and loss of personnel safety.

**Single Phase Protection Schemes:** There are many ways to provide single phase protection. One option is to provide a relay at each phase and interrupt the circuit when current flow in one of the phases is reduced to zero. The disadvantage of this scheme is that relays need to be shunted during the startup. Another option includes sensing voltages and phase angles on each of the three phases to detect single phasing. Modern day microprocessor based relays can provide enhanced protection by sensing currents, voltages and phase angles.

Protection of three phase motors from single phase operations is critical to ensure safety of operation. The NIH Design Requirement Manual (DRM) requires that all three phase motors shall be provided with single phase protection. Thermal overload protection and overcurrent devices may not always provide adequate single phase protection. Therefore, engineers must consider actual operating conditions to specify appropriate single phase protection mechanism.

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## Concrete and Sustainability

Concrete is one of the most widely used construction materials, so its impact on the environment must be understood to fully assess the sustainability of any construction project. Concrete is a global environmental concern because it is estimated that the cement industry produces 5% of global carbon dioxide (CO2) emmissions[1] and concrete use is increasing.

Cement is the active ingredient in concrete and Portland cement is the most common type of cement used in the Unites States. Portland cement, which typically constitutes 7 to 15% of concrete's mass by weight, reacts with water and air and hardens (carbonates), binding together fine and rough aggregate to form a solid, strong mass. The proportion of concrete, water and aggregates and the addition of additives are used to modify the characteristics of concrete to meet the requirements of a particular application.

**Environmental Concerns:**
The primary environmental concern is the CO2 produced during the manufacturing and carbonation of Portland cement. During manufacturing, limestone is heated in kilns at temperatures exceeding 1000°F for a long duration, in a process called calcination. Both the fuel required to heat the kilns and the calcification process produce large quantities of CO2. As the concrete sets and carbonates a large amount of CO2 is absorbed from the atmosphere, offsetting most of the CO2 released in the calcination process. The process is a net emitter of CO2, however, due to the energy required to heat the kiln. Considering the large volume of concrete used in some projects, the quantity of emitted CO2 can be substantial.

**Other Concerns:**
Portland cement is highly alkaline and exposure is limited by the Occupational Safety and Health Administration. The dust produced by the manufacturing of cement and the mixing and working of concrete and concrete demolition is hazardous and must be controlled.

**Environmental Advantages:**
Concrete has many characteristics which can offset the environmental concerns and make it a good choice for many applications:

- Most components of concrete (limestone, water, sand, gravel) can be locally sourced and the cement can be locally produced.
- Concrete is a very durable material and can last longer than other materials due to its resistance to rot, rust and insects. The life-cycle aspects of concrete should be considered when assessing its environmental impact.
- Concrete is noncombustible, so concrete elements usually do not require fireproofing. Concrete can also be left exposed, which can eliminate the need for finish materials.

Figure 1: Concrete structure and finish panels

- Pervious Concrete can be used for exterior flatwork, including sidewalks and low-load roads and parking areas. Pervious concrete allows the passage of water to the underlying soil, reducing the need for stormwater management systems.
- Concrete manufacturing can use industrial byproducts, removing them from the waste stream. Materials include fly ash, slag and silica fume.
- Hazardous organic and inorganic materials can be used as fuel for cement kilns and are destroyed by the extremely high operating temperature
- Concrete has a higher solar reflectance (albedo) than asphalt, and can effectively reduce heat island effect when used for sidewalks, roads and other horizontal surfaces.

**Recycling:**
Unlike other building materials (e.g. steel, glass, aluminum), Portland cement cannot be recycled and new cement must be manufactured for every installation. Concrete can be recycled, but at a lower installed value as the original installation. High value concrete elements (structural members, wall panels, etc.) can be crushed and used as fill, aggregate and other uses requiring inert volume. Care must be taken to ensure that the concrete is not contaminated with lead paint or other hazardous materials.

References

[1] The Cement Sustainability Initiative: Progress report, *World Business Council for Sustainable Development* (1 June 2002).

Further details on this month's topic are available on the DRM website:
Design Requirements Manual
DRM Chapter 1, Section 10 Sustainable Design