The sustainable-design movement is evolving from checking boxes in credit templates to holistic design. And in the search for holistic sustainable solutions, designers are seeking new insight through life cycle analysis and building modeling to evaluate a project’s impacts over its entire life. Certain attributes of sustainable buildings become increasingly important, such as:

- Energy
- Durability and resilience
- Reduced material manufacturing impacts
- Operational impact improvements
- Comfort—HVAC, noise, emissions

This article will update readers on steps the cement and concrete industries are taking to evaluate and reduce their environmental impact. It will also offer designers insight on how to increase sustainable performance on their projects through optimization of concrete applications in sustainable building. And to support this, the cement and concrete industry is developing detailed information to inform designers about the environmental impacts of their product choices.

EMBRACING TRANSPARENCY

The cement and concrete industry has embraced environmental transparency for some time, publishing its first industry-average LCA in 2000. Since then, the concrete industry has advanced its self-evaluation of environmental hot spots in its processes, and graduated to developing product category rules (PCR) and environmental product declarations (EPDs).

The Carbon Leadership Forum (CLF) at the University of Washington released a U.S.-specific PCR for ready mixed concrete in November 2012, which was revised in December 2013. In February 2013, the World Business Council for Sustainable Development (WBCSD) also announced the development of a PCR for unreinforced concrete.

Other concrete-related industry PCRs that have been published recently include:

- Slag Cement, published in August 2014,
- Portland, blended hydraulic, masonry, mortar, and plastic (stucco) cements, published in September 2014, and
- Manufactured Concrete and Concrete Masonry Products, published by ASTM in December 2014.
An industry-average environmental product declaration for ready mixed concrete was published by the National Ready-Mixed Concrete Association (NRMCA) in October 2014. NRMCA’s Industry-Wide Environmental Product Declaration (EPD) and Benchmark Report discloses average environmental impacts for concrete. These data are for concretes of varying strengths, uses, and mixture proportions. Several companies have also published EPDs for individual concrete-related products. Similarly, the U.S. cement industry expects to publish an industry average EPD for the most commonly used kinds of cement at the start of 2016.

**FUNDAMENTAL CONCRETE COMPONENTS**

To understand how the cement and concrete industries can reduce their collective environmental footprint, it is important to understand the components of concrete-related products. A unique attribute of concrete as a construction material is the ability to modify the proportion of ingredients in the mix design through specifications to achieve specific goals for the intended application. Concrete is primarily a mixture of two main components: aggregates and a binding paste. The paste is made up of minute amounts of other constituents to form portland cement.

Cement is produced in a rotary kiln. After the clinker has cooled, it is ground with gypsum, limestone, and very finely ground with gypsum, limestone, and other smaller quantities of clay, iron ore and sand (as sources of alumina, iron and silica, respectively). Increasingly, alternative sources from industry by-products (steel mill slag and scale, foundry sands, or bottom ash from coal fired power plants) can provide the essential elements for cement production.

The raw materials are heated to temperatures around 2700 degrees Fahrenheit (1500 degrees Celsius) to chemically transform the raw materials into clinker as it passes through the rotary kiln. After the clinker has cooled, it is very finely ground with gypsum, limestone, and minute amounts of other constituents to form portland cement.

**PORTLAND CEMENT**

Cement, which is typically 7 to 15% of the volume of concrete, provides the primary engineering and durability properties of concrete.

Portland cement is produced in a rotary kiln from a precise blend of constituents. The most common combination of ingredients is limestone (for calcium) along with much smaller quantities of clay, iron ore and sand (as sources of alumina, iron and silica, respectively). Increasingly, alternative sources from industry by-products (steel mill slag and scale, foundry sands, or bottom ash from coal fired power plants) can provide the essential elements for cement production.

Cement-plant carbon-dioxide emissions come from two sources: combustion and calcination. Combustion accounts for approximately 40% of the total CO₂ emissions from a cement manufacturing facility. The remaining 60% CO₂ emissions from calcining are formed when the raw material (limestone) is heated and CO₂ is stripped from the calcium carbonate molecules. This reaction enables the chemical formation with the other ingredients to achieve the hydraulic properties of portland cement. According to the U.S. EPA, 2013 U.S. greenhouse gas emissions totaled 6,673 million metric tons of carbon dioxide equivalents (CO₂e). Production of cement accounted for approximately 75.44 million metric tons of CO₂e or 1.1% of the U.S. national total.

The kiln’s combustion-generated CO₂ emissions are directly related to fuel use. Some of this energy comes from traditional sources, but over 73% of U.S. plants reporting in the 2013 PCA Labor-Energy Survey reported utilizing alternative fuels. Many plants use between 20 to 70% of alternative fuels for their energy requirement. Alternative fuels include waste oil, solvents, resins, scrap tires, refinery wastes, and other wastes that have high energy content. Cement kilns are one of the few options where these wastes can be safely and efficiently disposed, because of the high temperature in the kiln and the length of time exposed to this level of heat. The EPA has designated thermal destruction by energy recovery in cement kilns as the Best Demonstrated Available Technology (BDAT) for treatment of these wastes.

**ENERGY RECOVERY FROM WASTE**

The EPA recognizes tire derived fuel as a Best Management Practice and encourages industries to recover the energy from this waste stream while offering the added benefit of reducing the landfill for scrap tires. Tire derived fuel (TDF) has approximately 20% more BTUs than a comparable weight of coal, and since tires are manufactured in part with natural latex which literally grows in trees, TDF has a lower greenhouse gas impact than coal. The steel reinforcing belts in a tire are literally grown in trees, TDF has a lower greenhouse gas impact than coal. The steel reinforcing belts in a tire are more BTUs than a comparable weight of coal, and since tires are manufactured in part with natural latex which literally grows in trees, TDF has a lower greenhouse gas impact than coal.

The EPA has designated thermal destruction of waste to energy recovery as a best management practice for cement kilns. The length of time exposed to this level of heat can safely and efficiently dispose of these wastes. Cement kilns are one of the few options where these wastes can be safely and efficiently disposed, because of the high temperature in the kiln and the length of time exposed to this level of heat. The EPA has designated thermal destruction by energy recovery in cement kilns as the Best Demonstrated Available Technology (BDAT) for treatment of these wastes.

**SUPPLEMENTARY CEMENTITIOUS MATERIALS**

The addition of fly ash, slag and silica fume offers environmental and performance benefits when optimally combined with portland cement in concrete mix designs.
Supplementary cementitious materials (SCMs) such as fly ash, slag, and silica fume are industrial by-products which offer both environmental and performance benefits for concrete production. Fly ash is a residual from the combustion of pulverized coal in electric power generating plants. Slag cement is created from iron blast-furnace slag, a by-product of the steel-making industry. Silica fume is a waste created from the electric arc furnace used in the production of silicon or ferrosilicon alloy. In their 2014 Industry Wide EPD for Concrete, the ready mixed concrete industry reported that 95% of their plants use SCMs in their concrete products.

The intelligent use of SCMs can reduce the environmental footprint and contribute beneficially to the fresh and hardened properties of concrete. It is important to consider the impact on the properties of the concrete when determining the optimum amount of SCMs in a concrete mixture, which can affect water demand, curing times, durability, aesthetics, and other factors. Typical SCM proportions range from 15 to 40% of a mix design (by mass) and their use is also influenced by the local availability of these materials.

### Aggregate

Aggregates, constituting 60 to 75% of concrete by volume, are customarily sand, gravel, or crushed stone which are typically locally sourced, naturally occurring, with low embodied energy. A typical sand or aggregate quarry is considered relatively shallow and small in scale, closely contained and monitored compared to most mining operations. When closed, aggregate quarries are often converted to their natural state, or into recreational areas, or agricultural uses.

### Water

Water is essential to the hydration of cement in concrete. Almost any water suitable for drinking is acceptable for use in concrete. To improve water conservation, recently approved practices in concrete production include replacing some of the potable water with water reclaimed from previous concrete production, industrial processes and other water sources typically not used for human consumption.

### Admixtures

Chemical admixtures enhance the plastic and hardened properties of the concrete. Admixtures typically do not significantly affect the environment impact because they are used in such small quantities. Dosage rates are typically in the range of 0.005 to 0.2% of the concrete mass. They are primarily used to provide air entrainment, control set times, and improve workability in fresh concrete. When used in concrete for improved hardened properties, they can increase compressive strength, reduce shrinkage, and lower permeability. This can result in greater durability and longevity with a corresponding conservation of material resources and related environmental impacts.

### MIX DESIGN OPTIMIZATION

<table>
<thead>
<tr>
<th>4,000 psi Concrete</th>
<th>9,000 psi Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cementitious Materials in lbs per cu. yd.</td>
<td>550</td>
</tr>
<tr>
<td>Supplementary Cementitious in lbs per cu. yd.</td>
<td>110 (flyash)</td>
</tr>
<tr>
<td>Portland cement in lb per cu. yd.</td>
<td>440</td>
</tr>
<tr>
<td>Column cross section in inches.</td>
<td>36 by 36.</td>
</tr>
<tr>
<td>Concrete per column (15 ft) in yd.</td>
<td>5.00</td>
</tr>
<tr>
<td>Portland cement per column in lbs.</td>
<td>2200 lbs</td>
</tr>
<tr>
<td>Volume of cement reduction</td>
<td>16%</td>
</tr>
<tr>
<td>Volume aggregate reduction</td>
<td>55%</td>
</tr>
</tbody>
</table>

This results in a 16% net reduction for cement and a 55% reduction for aggregates, lowering the greenhouse gas footprint for these elements as well as providing an increase in net rentable floor area of 3120 s.f.

### CHARACTERISTICS OF SUSTAINABLE BUILDINGS

As we’ve become more knowledgeable and experienced in sustainability, we’ve come to expect more from our buildings and the products from which they are constructed. Concrete has certain inherent properties that aid in creating more-sustainable buildings such as:

- Durability and resiliency
- Heat island mitigation
- Lower embodied energy
CONTINUING EDUCATION

- Stormwater management
- Thermal mass
- Low or no volatile organic compounds
- Recyclable
- Local availability
- Sound attenuation

**Durability**

In determining the real value of a building, one must consider both the impacts over the entire life cycle of the project. Extracting optimal value from any material invested in a building demands durable products, design details and construction practices. Determining the impacts of material production is becoming more common as manufacturers publish data through EPDs. A key factor in building reuse and adaptability is the durability of the original structure and components. Structures require different types of durability depending on the intended use, environmental exposure and desired engineering properties.

Concrete components provide a long service life due to their durable and low-maintenance surfaces. Concrete can resist weathering action, chemical attack, moisture and abrasion while maintaining desired engineering properties. These characteristics of concrete make it sustainable in multiple ways: it avoids contributing solid waste to landfills, it reduces the depletion of natural resources, and the generation of air, water and solid waste from replacement materials. When properly designed, concrete structures can be reused or repurposed several times in the future.

**Quiz**

1. Where does the CO$_2$ originate in the cement manufacturing process?
   - a. Fuel combustion in the kiln
   - b. Calcination
   - c. Both a and b
   - d. None of the above

2. What volume of concrete is cement?
   - a. 7 to 15%
   - b. 15 to 30%
   - c. 30 to 60%
   - d. 60 to 80%

3. According to the EPA, 2013 cement plant greenhouse gas emissions were what percentage of the nation’s total emissions?
   - a. .36%
   - b. 1.1%
   - c. 5%
   - d. 10%

4. What percentage of alternative fuels do cement plants use for their energy?
   - a. 5 to 10%
   - b. 10 to 20%
   - c. 20 to 70%
   - d. 70 to 100%

5. True or false: Fly ash is a by-product of steel manufacturing.
   - a. True
   - b. False

6. What federal agency recognizes the durability of concrete by promoting concrete safe rooms for providing occupant protection from natural disasters?
   - a. Public Health Service
   - b. Federal Emergency Management Agency (FEMA)
   - c. U.S. Fire Administration
   - d. Transportation Security Administration

7. What is the solar reflectance value (SRI) of new concrete without added pigments?
   - a. >19
   - b. >29
   - c. >32
   - d. >78

8. How does one take into account the thermal mass benefits when modeling energy performance of a building?
   - a. Account for hourly heat transfer on an annual basis
   - b. Account for hourly heat transfer on an hourly basis
   - c. Account for annual heat transfer on an annual basis
   - d. Account for annual heat transfer on an hourly basis

9. What component of concrete is the greatest by mass?
   - a. Aggregate
   - b. Cement
   - c. Water
   - d. Admixtures

10. Increased outdoor temperatures due to the urban heat island effect, have been linked to what?
    - a. Greater air-conditioning loads
    - b. Reduced outdoor air quality
    - c. Increased cases of asthma
    - d. All of the above

**Sponsor Information**

Visit [http://go.hw.net/AR1115Course2](http://go.hw.net/AR1115Course2) to read more and complete the quiz for credit.

PCA represents America's cement manufacturers and has been a widely-recognized authority on the technology, economics, and applications of cement and concrete for nearly 100 years. PCA is a vocal advocate for sustainability, economic growth, sound infrastructure investment, and overall innovation and excellence in construction. More information on PCA is available at [www.cement.org](http://www.cement.org).
The longevity of concrete structures is readily apparent. As the most widely used building material in the world, concrete structures have withstood the test of time for many years. Depending on the application, the design service life of building interiors is often 30 years. However, the actual average life span for a building in the U.S. is 75 years; more than double the service life. The concrete portion of structures often lasts 100 years and longer.

It's for these reasons you often see concrete in essential infrastructure (bridges, dams, tunnels, runways and foundations) where long life is important. The Hoover Dam remains as one of the most recognizable structures of the 20th century. It was opened in 1936 and remains in service providing power, flood control and recreational areas in the largest man-made lake in the U.S. Built around the same time, the Rainbow Bridge is the largest single span concrete arch bridge in the State of Idaho and a landmark structure on the Payette River National Scenic Byway. Designed by Charles A. Kyle, the first chief bridge engineer in Idaho, the structure was to blend in gracefully with its stunning surroundings. The structure is a reinforced concrete arch bridge approximately 410 feet (125 m) in length with a main span approximately 210-feet (64 m) in length over the North Fork of the Payette River.

**RESILIENCY**

Properly designed reinforced concrete is resistant to fire, wind, hurricanes, floods, and earthquakes, and can also provide blast protection for occupants. The Federal Emergency Management Agency (FEMA) recognizes these attributes by promoting concrete safe rooms for providing occupant protection from natural disasters.

However, resilience is much more than natural disaster resistance. The increased robustness, longevity, and durability, combined with improved disaster resistance result in less energy and resources required for repair, removal, disposal, and replacement of building materials and contents due to routine maintenance and operations. Resilient buildings create safe, secure, comfortable, and productive communities in which to live and work. Concrete provide greater resilience helping essential service providers operating out of more robust fire and police stations, hospitals, and community shelters to continue operation after a disaster strikes.

**Fire resistance**

Noncombustible concrete buildings offer effective fire protection. As an exterior wall or roof, concrete helps to prevent a fire from involving other buildings. As an interior separation wall, concrete helps to prevent a fire from spreading within a structure. Concrete that endures a fire can often be reused when the building is rebuilt. During wild fires, concrete walls help provide protection to human life and the occupants’ possessions.

Concrete helps contain a fire even if no water supply is available, instead relying on a passive fire suppression technique. The fire endurance of concrete can be determined by its thickness and type of aggregate used.

**Tornado, hurricane, and wind resistance**

Concrete can be economically designed to resist forces from tornadoes, hurricanes, and wind. Hurricanes are prevalent in coastal regions. Tornadoes are particularly prevalent in the path of hurricanes and in the central plains of the U.S.

The amount of fatalities and property damage in these extreme wind events is far greater from the windblown debris than wind loads against the structure. Impact resistance of wall systems to tornado and hurricane debris missiles is tested using a 50 mm x 100 mm (2 in. x 4 in.) piece of wood travelling at 45 m/s (100 mph) and weighing 6.8 kg (15 lb). When tested against 3000 psi concrete walls as thin as 50 mm (2 in.), debris missiles shattered on impact without damaging the concrete.

A proven strategy to reduce life safety risk in extreme wind events is installation of a safe room. Federal Emergency Management Agency defines these as a hardened structure specifically designed to meet the FEMA criteria and provide near-absolute protection in extreme weather events, including tornadoes and hurricanes. Near-absolute protection means that, based on our current knowledge of tornadoes and hurricanes, the occupants of a safe room will have a very high probability of being protected from injury or death.

They offer design recommendations in a free publication titled FEMA P320 “Taking Shelter from the Storm” at this link: https://www.fema.gov/media-library/assets/documents/2009. It includes safe room designs and shows how to construct a safe room for homes or small business.

**Flood resistance**

Concrete is not damaged by water; in fact, concrete continues to gain strength in the presence of moisture. Submerged concrete absorbs very small amounts of water, even over long periods of time, and this water does not damage the concrete. Because of its inorganic mineral makeup, concrete does not rot, rust or offer a food source for mold. In flood-damaged areas, the concrete elements of flooded buildings are often salvageable by pressure washing.

**Earthquake resistance**

In reinforced concrete construction, the combination of concrete and reinforcing steel provides the three most important properties for earthquake resistance: stiffness, strength, and ductility. Reinforced concrete walls work well because of the composite capabilities of materials within the structural system: concrete resists compression forces, and reinforcing steel resists tensile forces produced by an earthquake. The stiffness of concrete walls also limit in-plane lateral movement (racking) which reduces damage to interior finishes and cladding.
HEAT ISLAND MITIGATION

Studies have shown that urban environments are 2°C to 4°C (3°F to 8°F) warmer than adjacent areas, and this phenomenon is called the urban heat-island effect. This temperature difference is attributed to the replacement of natural vegetation with buildings and pavements. Replacing dark roofing and paving materials with more reflective choices reduces heat island impacts. Concrete is an obvious material choice for reducing the urban heat island effect. New concrete without added pigments has an SRI value greater than 29, the threshold value required for hardscape in most green building standards and rating systems. ¹¹

Reflectance values can decrease over time as the pavement collects dirt and the cement paste at the surface is abraded. Pressure washing of the surface can restore much of the original reflectance.

STORMWATER MANAGEMENT

Concrete plays a significant role in conventional surface water management by providing conveyance and treatment infrastructure that is durable and impermeable. With the advent of sustainable design, there is considerable interest in replicating pre-development hydrologic site characteristics and concrete continues to offer solutions for design professionals and building owners. Since the primary cause of stormwater runoff is an increased impervious surface, sustainable site design seeks to minimize impervious surfaces as a first step. The second step is to manage the stormwater and minimize off-site discharge. This generally requires creating conveyance and storage features that initially store and allow for infiltration and absorption of stormwater. This has resulted in strategies that emphasize conservation and integration of on-site natural features with small-scale hydrologic controls.

Collectively, these strategies are known as Low Impact Development (LID). In addition to providing a more natural solution to stormwater management, low impact development strategies can reduce flooding and the need for large (and frequently expensive) conventional stormwater facilities such as expansive detention basins. Reducing the size of stormwater facilities can often result in more buildable land area particularly important on tighter, more densely developed sites.

Pervious concrete is a porous or no-fines concrete that has interconnected voids. Water percolates through these voids into the soil beneath the concrete system. If the absorptive capability of the soil is inadequate to effectively handle the anticipated runoff during a given period, the pervious concrete is placed over engineered granular base material, sized to provide temporary storage until the soil can absorb the runoff. For impervious soils, the storage layer of a pervious paving system can function as a detention basin, slowing the rate of discharge into a storm sewer system while enabling parking. Pervious concrete technology enables more efficient land use by eliminating the need for retention ponds, swales, and other stormwater management devices.

After several decades of in-place pervious pavements, well developed maintenance practices are available to address potential clogging and snow removal issues.

In pervious concrete applications, carefully controlled amounts of water and cementitious materials are used to create a paste that forms a thick coating around similarly sized aggregate particles. A pervious concrete mixture contains little or no sand, creating a substantial void content (typically between 15 and 25%). Using sufficient paste to coat and bind the aggregate particles together creates a system of highly permeable, interconnected voids that drains quickly. Water flow rates through pervious concrete are commonly measured at 0.34 cm/s (480 in./ft²/hr), which is 200 L/m²/min (5 gal./ft²/min), although they can be much higher.

Permeable interlocking concrete pavers and grid paver systems are constructed with special interlocking pavers that provide spaces between adjacent units. These spaces are typically filled with crushed granular material to allow water to infiltrate into the base of the pavement. The base course is designed to accept water so that it can be quickly diverted from the surface and provide a storage area that allows water to slowly percolate into the ground or to be controlled by other storm water management techniques.

Concrete pavers are made with dense concrete mixtures, come in a variety of shapes and can be colored or textured. As a result of their physical characteristics, pavers are durable in a
most climates and appropriate for a range of
loading and traffic. If utility or other subsurface
access is necessary, the pavers can be easily
removed and then replaced without damaging
the surface of the pavement.

LOW OR NO VOCs
Reducing uncontrolled air infiltration is an integral
part of building energy efficiency, but has lead to
a decrease of indoor air quality. Concrete contains
low to negligible volatile organic compounds
(VOCs). These compounds degrade indoor air
quality when they off-gas from new products. In
addition, VOCs combine with other chemicals in
the air to form ground-level ozone. Complaints
due to poor indoor air quality routinely include
eye, nose, and throat irritation, dizziness and
increased incidence of asthma.

Decorative concrete finishes can be integral
to the interior or exterior surface of concrete
walls and the walking surface of concrete slabs.
Exterior decorative finishes eliminate the need
for additional maintenance and replacement of
short lived coatings. Interior decorative finishes
eliminate the need for gypsum wallboard and
also provide a durable inside surface.

THERMAL MASS
Centuries before the introduction of air condi-
tioning, the integration of thermal mass and
convection strategies enabled builders to create
structures that worked with nature to keep
occupants more comfortable. Fundamental for
passive solar design but effective in most all
environments and energy efficient strategies,
buildings constructed of cast-in-place, tilt-up
or precast concrete, insulating concrete forms
(ICF) and masonry possess thermal mass that
helps moderate indoor temperature extremes
and reduces peak heating and cooling loads.
This means concrete components have enough
heat-storage capacity to moderate daily
temperature swings.

The thermal-mass advantages of concrete
should be utilized when designing for passive
thermal strategies or minimizing energy use in a
building. In many climates, these buildings have
lower energy consumption than non-massive
buildings with walls of similar thermal resis-
tance. When buildings are properly designed
and optimized, incorporating thermal mass can
lead to a reduction in heating, ventilating, and
air-conditioning equipment capacity. Reduced
equipment capacity can represent both energy
and capital equipment cost savings.

The ASHRAE Standard 90.1—Energy Standard
for Buildings Except Low-Rise Residential
Buildings, the International Energy Conservation
Code and most other energy codes recognize
the benefits for thermal mass and require less
insulation for mass walls. It is important when
modeling energy performance of a building to
take into account the thermal mass benefits.
Computer programs such as DOE-2 and
EnergyPlus can take into account hourly heat
transfer on an annual basis, which allows for
more accurate determination of energy loss in
buildings with mass walls and roofs.

RECYCLABLE
Concrete is a relatively heavy construction
material, yet is frequently crushed and recycled
into aggregate for road bases or construction
fill. The Construction Materials Recycling
Association estimates that approximately 140
million tons of concrete is recycled annually.
This reduces the amount of material that is
landfilled and the need for virgin materials
in new construction. Concrete pieces from
demolished structures can also be reused in
stacked landscaping walls, gabion walls or
as riprap for shoreline protection. Recycled
concrete can also be used as aggregate in new
concrete, particularly as the coarse aggregate.

LOCAL AVAILABILITY
Concrete, and its constituent materials, are
typically sourced locally. For example, ready-mix
and precast concrete plants generally use
aggregates that are extracted within 50 miles of
the plant. Cement and supplementary cemen-
tious materials used for buildings are also often
manufactured within 500 miles of a job site.
Reinforcing steel is usually manufactured within
500 miles of a job site, and is typically made
from recycled materials from the same region.

According to the National Ready Mixed
Concrete Association, the average distance
between the batch plant and the project site
is 14.2 miles. Most precast concrete plants are
within 200 miles of the project site. Reduced
shipping distances associated with local
building materials minimize fuel requirements
and the associated energy and emissions from
transportation and handling. Locally produced
materials contribute to the local economy and
reduce imports of materials that may have been
produced in countries with much less stringent
environmental regulations than in the U.S.

SOUND ATTENUATION
Recent research has revealed that densely
populated urban environments have the
lowest carbon footprint per capita, with a
significant influence from reducing automobile
usage. However, high density also puts
habitants close to noisy infrastructure and
neighbors. Concrete provide the necessary
mass to dampen sound from one space to
the other. Assemblies with higher Sound
Transmission Class values offer greater the
sound attenuation. Concrete block or cast
concrete partitions can be used to separate
CONTINUING EDUCATION

CONTINUING EDUCATION

mechanical rooms and HVAC equipment, work areas and noisy areas such as lobbies and public corridors from adjacent living space.

CONCLUSION

Sustainable design and construction is motivating designers and building owners to re-evaluate the materials, methodologies and metrics for optimal building performance over decades of service. For the type of essential applications that concrete is selected to perform, it consumes minimal materials, energy, and other resources for construction, maintenance, and rehabilitation over its lifetime, while providing safe and essential infrastructure to society. Concrete’s proven performance is enhanced by the designer’s ability to specify a mix design tailored to the application's goals.

For the latest in cement and concrete research for sustainable applications, please visit the Massachusetts Institute of Technology Concrete Sustainability Hub at https://cshub.mit.edu.

Join us on Twitter or Facebook for breaking news, Fast Facts, and new product and project developments at http://twitter.com/PCA_Daily and https://www.facebook.com/ThinkHarder.Concrete

Table 1–Dept. of Housing and Urban Development, “Sound Transmission Class Guidance”, Chapter 4 Supplement.

<table>
<thead>
<tr>
<th>STC</th>
<th>What can be heard</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>Normal speech can be understood quite easily and distinctly through wall</td>
</tr>
<tr>
<td>30</td>
<td>Loud speech can be understood fairly well, normal speech heard but not understood</td>
</tr>
<tr>
<td>35</td>
<td>Loud speech audible but not intelligible</td>
</tr>
<tr>
<td>40</td>
<td>Onset of “privacy”</td>
</tr>
<tr>
<td>42</td>
<td>Loud speech audible as a murmur</td>
</tr>
<tr>
<td>45</td>
<td>Loud speech not audible; 90% of statistical population not annoyed</td>
</tr>
<tr>
<td>50</td>
<td>Very loud sounds such as musical instruments or a stereo can be faintly heard; 99% of population not annoyed</td>
</tr>
<tr>
<td>60+</td>
<td>Superior soundproofing; most sounds inaudible</td>
</tr>
</tbody>
</table>

Table 1

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<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2&quot; x 4&quot; studs and 16&quot; o.c. w/ ½&quot; gypsum drywall (both sides)</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>2&quot; x 4&quot; studs spaced 16&quot; o.c. and staggered 8&quot;o.c. on 2&quot; x 6&quot; plates w/ ½&quot; gypsum drywall (both sides)</td>
</tr>
<tr>
<td>22</td>
</tr>
<tr>
<td>Two separate 2&quot; x 4&quot; stud walls 16&quot;o.c. on separate plates spaced 1&quot; apart w/ ½&quot; gypsum drywall (both exterior faces)</td>
</tr>
<tr>
<td>29</td>
</tr>
<tr>
<td>Two separate 2&quot; x 4&quot; stud walls (16&quot; o.c). on separate plates spaced 1&quot; apart w/ ½&quot; gypsum board on exterior faces. Both stud cavities filled with 2 ¼&quot; thick sound attenuation blankets.</td>
</tr>
<tr>
<td>36</td>
</tr>
<tr>
<td>6&quot; x 8&quot; x 16&quot; 3-cell lightweight concrete masonry units (21 lbs./block). Paint both sides with primer-sealer coat and finish with latex paint.</td>
</tr>
<tr>
<td>37</td>
</tr>
<tr>
<td>8&quot; x 8&quot; x 18&quot; 3-cell lightweight concrete masonry units (38 lbs./block). Fill cells with expanded mineral loose-fill insulation.</td>
</tr>
<tr>
<td>41</td>
</tr>
<tr>
<td>6&quot; cast concrete wall (71 psf)</td>
</tr>
<tr>
<td>43</td>
</tr>
<tr>
<td>6&quot; cast concrete wall (71 psf) with ½&quot; gypsum drywall on one side over 2&quot; x 2&quot; furring and 1½&quot; (4 pcf) rockwool</td>
</tr>
<tr>
<td>48</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6&quot; x 8&quot; x 16&quot; 3-cell lightweight concrete masonry units (21 lbs./block). Paint both sides with primer-sealer coat and finish with latex paint.</td>
</tr>
<tr>
<td>20</td>
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<tr>
<td>8&quot; x 8&quot; x 18&quot; 3-cell lightweight concrete masonry units (38 lbs./block). Fill cells with expanded mineral loose-fill insulation.</td>
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<tr>
<td>22</td>
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<tr>
<td>6&quot; cast concrete wall (71 psf)</td>
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<tr>
<td>24</td>
</tr>
<tr>
<td>6&quot; cast concrete wall (71 psf) with ½&quot; gypsum drywall on one side over 2&quot; x 2&quot; furring and 1½&quot; (4 pcf) rockwool</td>
</tr>
<tr>
<td>26</td>
</tr>
</tbody>
</table>

REFERENCES

1 Carbon Leadership Forum (CLF). 2013. Product Category Rules (PCR) for ISO 14025 Type III Environmental Product Declarations (EPDs) of Concrete, Revised Version 1.1, December 4, 2013: CLF.
2 World Business Council on Sustainable Development (WBCSD). 2013. UN CPC 375 Concrete Product Category Rules, version 1.0: WBCSD.
7 Blumenthal, M., “The Use of Scrap Tires in Rotary Cement Kilns, Scrap Tire management Council, Washington DC, 1996