SECM/15/045

APPICATIONS OF ENVIRONMENTALLY FRIENDLY CELLULAR CONCRETE IN CONSTRUCTION

Rupa Purasinghe[1], F. Shimose[2], H. Lum[2], J. Shamma[2]

[1]California State University at Los Angeles, CA 90032, USA

[2]California State University at Los Angeles, CA 90032, USA

[1]E-Mail: rpurasi@calstatela.edu, TP: +001-323-343-4459

Abstract: Cellular concrete is a cost effective construction material that is continuously gaining traction and popularity in the US and elsewhere. Cellular concrete is a material consisting of Portland cement, water, and foam. When it hardens, the concrete has an oven-dry density ranging from approximately 50 lbs/cubic feet to 90 lbs/cubic feet. Some applications have achieved an even lower density that 50 lbs/cubic feet. Recipes may also include aggregates such as fly ash. Admixtures are used as well depending on the final use of the product. Cellular concrete has numerous applications in the building construction industry and as an underground backfilling material, but lately other uses in the infrastructure field have been gaining popularity especially as a stabilizer around transmission conduits. Popular application of cellular concrete includes insulation, fire retarding, and sound proofing for a variety of structures. Cellular concrete systems provide better drainage, increased fire resistance, increased wind uplift ratings, improved seismic values, efficient thermal insulation, and improved sound attenuation in an environmentally friendly manner. In underground applications, cellular concrete is used as a cost effective filler material in lieu of soil without the compaction effort required when using soil. Most recently the infrastructure field introduced cellular concrete as a backfill and filler material around underground structures such as segmental tunnel liners and pipelines. Cellular concrete can be used as backfill material at pipeline fault crossing by allowing localized ground deformation without overstressing the pipe section. This application can minimize damage to the pipeline or tunnel transmission structure that results from a shear failure of the pipe. However, the low compressive strength of cellular concrete limits its application as a structural material. The paper discusses material behavior and characteristics, state of the art construction methods, and advantages and disadvantages of using cellular concrete as a construction material in current times.

Keywords: Cellular concrete, fire resistance, green roofs, pipeline backfill, thermal insulation, tunnel annular space backfill.

1. Introduction

1.1 Process and Mixture of Cellular Concrete

The cement used in the preparation of cellular concrete is designed to meet the requirements of ASTM C150 (Portland cement), C 595 (blended cement), or C 1157 (hydraulic cement). The water/cement ratio ranges from 0.5 to 0.6 and is similar to that of the normal weight concrete. Low-density cellular concrete may include lightweight aggregates such as vermiculite meeting the requirements of ASTM C332.

Cellular concrete is produced by adding a chemical admixture to a hydraulic cement and water such that the resultant concrete is a low density product through air-entrainment. The air entrainment forms air voids inside the structural matrix giving it its low density. Usually this added chemical or material is a proprietary foaming agent. The resultant product, when hardened, has a density ranging from 50 lbs/cubic feet to 90 lbs/cubic feet. Compressive strengths range from 160 psi to 300 psi. Some contractors have been able to reduce the density further by modifying their foam and mixing processes. Others have created more elaborate recipes that include materials such as fly ash, special admixtures, and lightweight aggregates. Cellular concrete can be pumped over long distances with proper air-entrainment, thus allowing it to be used in a variety of applications not conducive if using regular concrete.

2. Properties of Cellular Concrete

2.1 Physical Properties

Cellular concrete is a low density product and behaves like a viscous fluid where the interaction between molecules offers little resistance to sheer deformation prior to hardening. This property allows cellular concrete to have self-leveling properties, good workability, and most importantly self-consolidation which eliminates the need for compaction and vibration. The texture/color of air dry cellular concrete is of a rough light gray color riddled with air voids as shown in figure 1 below.

(Courtesy of ACI 523.3R-14)
Figure 1: Texture/Color of Cellular mix

2.2 Temperature & Curing

ACI 523.3R-14, discusses precautions to be taken when concreting in cold weather and recommends not to place cellular concrete in rain, or snow. In fast drying conditions, a wet curing or curing compound should be used. For mass fill applications such as in geotechnical or underground applications, curing takes place in between fresh lifts placed on successive days (ACI 523.3R-14, Chp.4.4).

2.3 Density and Compressive Strength

Compressive strength is dependent on water-cement ratio, density, type of cement used, and aggregate types. Cellular concrete may be designed for densities varying from 50 lbs/cubic feet up to about 90 lbs/cubic feet. For roof insulating concrete and underground fill projects the density is normally below 60 lbs/cubic feet. This helps to maintain its lightweight material properties with improved workability. The use of fly ash, sand and other lightweight aggregates can be added to further enhance its density and strength.

3. Equipment and Mixing on Site

3.1 Equipment Used

Equipment for the production of cellular concrete is varied depending on the use, application, and/or capacity requirements of the task. Many large jobs utilize production plants that are skid mounted and can be moved around the site with ease. Most of these plants are automated in order to achieve the desired consistency for the particular job.

4. Cellular Concrete Applications

4.1 Construction of Buildings Applications of Cellular Concrete

4.1.1 Insulating Concrete Roof Application

A common application of cellular concrete is as insulation material for roofs. In most applications cellular concrete is either used by itself or coupled with insulation foam to provide required insulation. Usually cellular concrete is placed atop a galvanized steel deck and topped off with a roofing material. The cellular concrete is permanent as it does not deteriorate with time and does not require replacement over the life of the structure.

4.1.2 Floors and Decks

Cellular concrete is used for decks and floors where thermal insulation and noise control are requirements of the designer. This is due to its ability to dampen noise and act as an insulator. The use of cellular concrete provides a cost effective way to install floors in apartment buildings and high rises since the material is low density and has great workability. Cellular concrete as an insulator can be used in applications that require an insulating material that has integrity and strength.

4.1.3 Fill Material

Currently, cellular concrete is gaining confidence among the engineering and geotechnical community as a geotechnical fill or ground improvement material. Its popularity is even more so due to its low cost, no compaction requirement, and rapid construction.

4.1.4 Wall Panels

Cellular concrete is also utilized in the construction of precast wall systems for residential and commercial buildings. Its lightweight nature coupled with its resistance to moisture damage makes it a practical and an environmentally friendly product. British Columbia researchers (Dr. Rishi Gupta, P.Eng. of British Columbia Institute of Technology), has developed the use of precast light gage steel wall systems using cellular concrete as filler (Figure 2). Hospitals, high rise building, gas stations, commercial buildings, retail outlets, ATM kiosks, modular washrooms, modular cabins, and site offices and customized buildings are all conducive for the use of cellular concrete wall systems. The lightweight nature of the product allows it to be placed in site or shipped to the site after being formed and poured at a precast facility. This type of construction has proved to be economical in many applications.

Research have determined that the use of cellular concrete in light gage steel wall systems provides an increase in the axial load carrying capacity helping the building structurally. Also, cellular concrete serves as an efficient fire proofing insulator, providing a one hour fire rating per inch of thickness. It also has thermal resistance capabilities that help protect the occupants of a building in case of a fire. The use of cellular concrete wall systems is believed to also reduce the deteriorations of walls due to environmental aspects.

(Courtesy of British Columbia Institute of Technology. http://metro-panels.com/media/ARTICLE%20BY%20FACULTY%20AT%20BRITISH%20COLUMBIA.pdf)

Figure 2: Light Gage Steel with Cellular Concrete in-fill

4.2 Geotechnical Applications of Cellular Concrete

Cellular concrete has a lower density than compacted soil, and it is an efficient void-filling material without surcharging existing facilities or pipelines. Cellular concrete can be used to replace soil and the engineers can prepare it such that it has the desired strength for any particular application including jobs that require it to supplement existing soil strength.

4.3 Underwater Applications of Cellular Concrete

Cellular concrete has been successfully used underwater in such applications as those requiring the encapsulation of timber thus insulating the timber for underwater organisms that contribute to its deterioration. Because cellular concrete remains cohesive during pumping and placing allows it to work well underwater. The most important requirement when placing cellular concrete under water is that is has a higher density than water allowing it to displace water and not disperse. This also gives it the ability to fill in small underwater voids.

4.4 Pipeline and Tunnel Backfill

4.4.1 Pipeline Trench Backfill

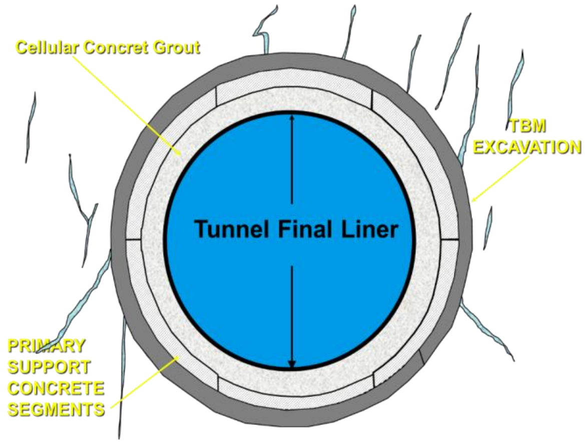
For pipeline construction in a vertical trench support system, the space between the pipeline and vertical shoring and/or the trench wall may be too tight to allow proper compaction of soil backfill. In cases like this, cellular concrete can be used to fill the void surrounding the pipeline. Cellular concrete can be an economical solution to fill the voids while providing corrosion protection for the pipe. With the proper mix design, cellular concrete can be pumped over a long distance which helps when performing work in tight areas or when the construction schedule is a constraint.

4.4.2 Conduits at Fault Crossings

For conduit (pipeline and tunnel) construction across active faults, cellular concrete can be used as annular filler around a pipeline to accommodate ground movement during fault offset without damaging the pipeline. This is usually done by creating a chamber around the pipeline or oversizing a trench area and then filling the cavity around the pipeline with very low density cellular concrete. When a seismic event occurs, the cellular concrete will crush and deform to accommodate the displacement while maintaining alignment of the existing pipeline.

4.4.3 Tunnel Annular Backfill

For a two-pass tunnel lining system for water or wastewater construction, the primary liner (such as concrete segmental liner) provides the initial ground support while the final liner (such as welded steel pipe) is constructed inside the primary liner. The gap between the primary liner and the final liner is known as the annular space. Cellular concrete is widely used as backfill material to fill the annular space to provide corrosion protection, final liner support and a continuous load path between the pipeline and the surrounding ground. Cellular concrete is pumped for a long distance inside the final liner and flows through grout ports along the liner to fill the voids. The placement sequence of concrete backfill is tightly controlled inside the liner to ensure proper dissipation of heat of hydration and prevent pipe floatation associated with the low fluid density of cellular concrete.



(Courtesy of Howard Lum)

Figure 3: Typical Tunnel Cross-Section showing cellular concrete grout

(Courtesy of Howard Lum)

Figure 4: Cellular concrete pumped in the annular gap of a tunnel

5. Cellular Concrete – Advantages and Disadvantages

5.1 Advantages

Cellular concrete is finding its way in many aspects of the construction industry and has been replacing a variety of materials. Some of the reasons for cellular concrete are:

- Low density characteristic
    - Low density results in reduced loading on substructures
- Lightweight characteristic
- Easy to pump
    - Fluidity and air content make it easy to pump over long distances
- Self-leveling
- Easy to use to fill small voids
- Does not need to be compacted
- Easy placement with proper pumping equipment
- An insulator
    - Reduces noise transmission
    - Thermal insulation
- Can be safely removed and reused
- Provides shock and energy absorption. If compressed during impact, resistance increases and kinetic energy is absorbed.
- Cost efficient.

5.2 Disadvantages

- Low compressive strength compared to normal weight concrete
- Not as durable and will not resist structural loads
- Requires more precise control in pumping and placement

6. Summary

Cellular concrete is getting increased attention as a construction material due to its versatility, lightweight nature, low cost, and environmentally friendliness. Cellular concrete is a material consisting of Portland cement, water, and foam. Recipes may also include admixtures such as fly each to accommodate a variety of applications. Cellular concrete has numerous applications in the building construction industry and as an underground backfilling material, but lately other uses in the infrastructure field have been gaining popularity especially as a stabilizer around transmission conduits. Popular application of cellular concrete includes insulation, fire retarding, and sound proofing for a variety of structures. Cellular concrete systems provide better drainage, increased fire resistance, increased wind uplift ratings, improved seismic values, efficient thermal insulation, and improved sound attenuation in an environmentally friendly manner. In underground applications, cellular concrete is used as a cost effective filler material in lieu of soil without the compaction effort required when using soil. Most recently the infrastructure field introduced cellular concrete as a backfill and filler material around underground structures such as segmental tunnel liners and pipelines. Cellular concrete can be used as backfill material at pipeline fault crossing by allowing localized ground deformation without overstressing the pipe section. This application can minimize damage to the pipeline or tunnel transmission structure that results from a shear failure of the pipe. However, the low compressive strength of cellular concrete limits its application as a structural material.

References

[1]. American Concrete Institute ACI 523.3R-14, April, 2014, Guide for Cellular Concretes above 50lb/ft^3.

[2]. American Concrete Institute ACI 523.1R-06, August, 2006, Guide for Cast-in-place Low-Density-Cellular Concrete

[3]. Institute of Technology, Nirma University, Ahmedabad. "The Innovative Precast Light Gauge Steel Wall System Combined with Cellular Concrete" Dr. Rishi Gupta, P.Eng. British Columbia Institute of Technology, December, 2011 *http://metro-panels.com/media/ARTICLE%20BY%20FACULTY%20AT%20BRITISH%20COLUMBIA.pdf*

[4]. Cell-Crete Corporation, www.cell-crete.com

[5]. Elastizell Corporation of America, www.elastizell.com

[6]. Geofill LD Marine, www.geofill.com

[7]. L.R.E. Ground Services Inc., www.lregsi.com