

## **Precast Concrete Wall Panels vs. Traditional Tilt-Up Concrete Walls vs. 3D Printed Concrete Walls**

### **Precast Concrete Wall Panels**

Precast concrete wall panels, also referred to as prefabricated concrete walls, are concrete wall panels engineered and manufactured almost entirely in a controlled factory environment before being transported to the construction site. Sometimes called plant-cast concrete wall panels, these concrete walls are designed to be strong, durable, and versatile.

#### **Materials – Composition**

Precast concrete wall panels are made from a variety of materials. The ratio of materials can differ based on desired strength, durability, and aesthetic appeal. The main material used in precast concrete walls is, of course, concrete. Made by mixing cement, water, aggregate (sand, gravel, or crushed rock), and sometimes admixtures, the concrete is then poured into a mold to achieve the desired shape and size.

These concrete panels are often reinforced to increase the wall's strength and durability. The reinforcement is typically placed inside the concrete before it hardens, and it helps the concrete to resist tensile forces, which are forces that tend to pull things apart. This reinforcement can come in many forms including but not limited to prestressing materials, deformed bars, and welded wire fabric.

Precast concrete wall panels can be insulated for energy efficiency. This is achieved using materials like expanded polystyrene (EPS), extruded polystyrene (XPS), or polyurethane foam. Insulation can give precast concrete walls a high effective R value. The higher the R value, the better a material is at resisting heat flow, therefore, the higher a material's R value, the greater its insulation properties. Unlike the standard R-value, effective R-value includes the cumulative effect of all the materials used in the construction of a particular element of a structure when determining the thermal resistance of a construction material.

#### **Labor – Quantity, and Type**

The manufacturing and installation of precast concrete wall panels is done in several steps, each requiring different types of labor. This begins with skilled engineers and architects who design the precast concrete wall panels according to the specifications of the project. Then, after these designs are approved, they are sent off to be manufactured. The manufacturing process requires a variety of people including production workers, quality control technicians, supervisors and equipment operators. After design and production, the precast concrete wall panel must be transported to the construction site. This means truck drivers and logistic personnel must be employed. Following transportation, construction workers, such as crane operators, site

supervisors, projects managers, safety personnel, and others are needed to complete installation. The exact number of laborers needed in each category will depend on the scale of the project, the complexity of the designs, the size and number of panels being manufactured and installed, and the efficiency of the equipment and processes used.

### Equipment – Quantity, and Type

Like labor, equipment quantity and type involved in the manufacturing and installation process of precast concrete wall panels varies based on the scale, budget, and complexity of the project. This will serve as an overview of the equipment that may be necessary in the manufacturing and installation process.

- Precast Concrete Wall Manufacturing Plant – It may seem obvious, but a high quality and efficient manufacturing plant is necessary to produce the right walls for a structure and ensure quality control. These manufacturing plants will need things such as rebar cutters to install the concrete reinforcement, concrete poring equipment, vibration equipment to remove any air bubbles from the product, and curing equipment. One of the benefits of using prefabricated concrete wall panels compared to traditional tilt-up concrete walls is that the production process can be outsourced.
- Trucks for transportation – Flatbed trucks are generally used for transporting precast concrete walls from the manufacturing plant to the construction site. The number of trucks required varies depending on the number of panels that need to be transported and the speed at which they must arrive at the construction site.
- Cranes – Cranes are crucial for lifting the precast concrete wall panels into their desired places. A variety of cranes can be utilized in this process including mobile cranes, telescoping cranes, and tower cranes. The process of lifting the precast walls into place often requires additional tools and equipment such as spreader bars which are typically used in combination with cranes to evenly distribute the weight of the panel and prevent damage during lifting, rigging equipment used to connect the crane to the concrete panel, and lifting clamps (grippers) which can be used to securely grip the concrete panels during lifting.
- Concrete Braces – Concrete braces are used to stabilize the precast panels during installation.

A variety of other equipment is required when transporting and installing prefabricated concrete wall panels including equipment necessary to ensure speedy and efficient installations as well as ensure the safety of all workers.

### Speed and Efficiency

Prefabricated concrete wall panels are cast and cured in a factory or manufacturing plant which reduces the need for on-site labor. This can speed up construction and improve efficiency. However, compared to traditional tilt-up concrete wall panels and 3D printed concrete walls,

projects using precast concrete wall panels can lose a lot of time in transport. This is because traditional tilt-up concrete wall panels and 3D printed concrete walls are created on-site whereas precast walls are not. So, while utilizing precast concrete wall panels in a project can reduce the amount of time needed for curing and formwork on-site, the need to move the panels from the factory to the construction site can potentially cause delays and increase costs.

## Sustainability

Like most modern construction methods, the sustainability of precast concrete walls is a mixed bag. While there are several advantages that can contribute to sustainable building practices, they also have negative environmental impacts.

Some of the advantages of precast concrete walls include the durability and longevity compared to other construction materials and the recyclability of concrete. With proper care and maintenance precast concrete walls can last for decades reducing the need for demolitions and replacement which saves resources, labor, and money over time. Additionally, Concrete can be crushed and reused as aggregate for new concrete or for road bases, reducing the need for new raw materials.

## Traditional Tilt-Up Concrete Walls

Installing traditional tilt-up concrete wall panels is like raising a barn, but the wooden panels are replaced with a thick slab of concrete. Tilt-up concrete wall panels are cast on-site. Horizontal molds are filled with concrete creating large slabs called “panels”.

### Materials – Composition

Traditional tilt up concrete walls are made of the same material as precast concrete walls panels. This includes concrete made from cement, water and aggregates like sand or gravel and reinforcement such as steel rebar or wire mesh embedded within the concrete for added strength and to prevent cracking. The concrete is cast into a mold on-site and like precast concrete wall panels can be insulated. Once the concrete has cured, the forms are removed, and the panels are tilted up into place using a crane. Once erected, the panels are braced until the roof and other structural elements are in place to secure the building structure.

The composition and installation of traditional tilt-up concrete wall panels and precast concrete wall panels are very similar. The primary difference is where the walls are made. Where prefabricated walls are made in a manufacturing plant or factory, tilt-up walls are made on-site.

### Labor – Quantity, and Type

The process of making and installing traditional tilt-up concrete requires many different types of skilled labor. Just like with any type of building, it starts with the designers and architects who ensure that the tilt-up wall design and specifications will meet the required structural, aesthetic, and building code requirements. Structural engineers are then needed to calculate the necessary reinforcement to make the wall both functional and safe. Before the wall concrete can be poured, site workers and operators must prepare the construction site. Preparations must be completed so that the structure is ready for the wall to be installed when curing is done and so that the exact site at which the concrete is going to be poured is ready.

It is recommended that concrete workers are employed (workers who specialize in concrete) to pour and finish the concrete slabs that will become the tilt-up concrete wall panels. Because the walls are made onsite, all quality control requirements and responsibilities fall to the construction contractor. This contrasts precast concrete wall panels where quality control falls to the manufacturing plant or factory at which the panels are cast.

Once the concrete slab is reinforced, cured, and checked for quality, the installation is similar to that of precast walls. Construction workers such as crane operators, riggers, and insulation installers are employed to make sure that the wall is properly installed. It is important to note that this is not a comprehensive list of necessary workers, but a general list and that these roles may vary based on the specific project, and some roles may be filled by the same individuals depending on their skill sets.

#### Equipment – Quantity, and Type

Because traditional tilt-up concrete wall panels are manufactured on site, the list of on-site equipment required may be greater than that of precast concrete wall panels.

- Formwork – Formwork are the molds into which the concrete mixture is poured. These molds can be made from a variety of materials including wood, metal, and plastic. Formwork is used to ensure that the concrete wall is made to the exact shape and dimensions required.
- Cranes – Just like in precast concrete wall panel, cranes are used to get the tilt-up concrete walls into place. The type and size of crane depends on the size and weight of the panels.
- Bracing/Rigging Equipment - Braces are necessary to hold the panels in place once they've been lifted, while rigging equipment, including lifting inserts, spreader bars, and cables, is needed for the safe lifting and handling of the panels.
- Concrete Mixer and Pump – A concrete mixer is necessary to both mix and house the concrete until it is ready to be poured. Additionally, if the casting bed is not reachable directly by the mixer, then a concrete pump may be required to pour the concrete at the desired location.
- Concrete Finishing Tools - Trowels, floats, edgers, and other finishing tools may be necessary to achieve the proper shape and achieve a smooth surface.

## Speed and Efficiency

Casting the walls on-site eliminates the need for lengthy delivery times or off-site construction. This can increase the speed and efficiency of construction. However, more time is spent waiting for the concrete slabs to settle and cure and in finishing. When the walls are precast, curing and finishing occur at the manufacturing plant or factory as opposed to time spent on-site. The onsite construction allows for greater flexibility and adaptability to unique project requirements, but it can be less efficient in situations with limited site space or unfavorable weather conditions as these can disrupt the casting and curing process. When working on site with ample space, tilt-up construction may be more efficient while precast may be more efficient in regions with frequent inclement weather or when dealing with limited site space.

## Sustainability

Traditional tilt-up concrete wall panels share many of the same environmental impacts as precast concrete wall panels. Concrete walls can be energy efficient because they offer excellent thermal mass. This helps regulate the temperature inside the building which can save energy in the heating and cooling process. These walls are also highly durable, meaning they have high longevity which can reduce the environmental impact associated with frequent repairs and replacements. There are negative environmental impacts as well. Traditional concrete is made with cement. The production of cement produces a significant amount of carbon-dioxide as a byproduct. Additionally, the extraction of raw materials necessary to produce concrete can be harsh on the environment, leading to habitat loss and harm biodiversity.

## **3D Printed Concrete Walls**

3D printed concrete wall panels are built on-site like traditional tilt-up concrete walls. However, 3D printed concrete, also called additive manufacturing of concrete (AMoC), involves using an industrial concrete 3D printer to build the walls layer by layer. This relatively new technology has been revolutionizing the construction industry in recent years because it can serve as a faster, more cost effective, more environmentally friendly, and more efficient option to some traditional building methods.

## Materials – Composition

3D printed concrete walls are made primarily of a special type of concrete designed specifically for 3D printing. The composition of printable concrete can vary based on the producer. Some printable concrete is made from waste products from other industries or recycled concrete. Additionally, there are many projects underway to make printable concrete, or concrete ink, even more environmentally friendly by making it from “green concrete”. Typical 3D printed

concrete walls feature the same materials as other types of concrete walls including cement, aggregates, water, and additives.

Fibers are also often added to printable concrete to improve the tensile and flexural strength of the printed concrete. For example, steel or glass might be added. This can help to control cracking and add overall durability to the 3D printed walls. This can be used to replace traditional steel or mesh reinforcements.

### Labor – Quantity, and Type

It is a common misconception that using 3D printing technology in the construction industry is replacing jobs, and therefore replacing people. In reality, there are no statistics to support this claim. A more apt description is that the jobs are shifted. As with precast concrete wall panels and traditional tilt-up wall panels, the process begins with designers, architects, and engineers. These experts must have knowledge of architecture and civil engineering. From there, a 3D modeling expert may be hired to translate the chosen design into a 3D model that the printer can interpret.

Additionally, as printable concrete is a relatively new technology, a material expert may be necessary to determine the optimal concrete mix for the structure and the 3D printer. Depending on the type of concrete printer used, a professional 3D printer operator may be needed. This person would run the 3D printer and would know how to load the printer, start the print, and monitor it for any issues that may arise. They may also need to perform maintenance on the printer. Construction site workers are also necessary to monitor construction and complete sections of the structure or wall that are not 3D printed. As with any construction project, a project manager is necessary to oversee the entire project from start to finish. They coordinate between the different labor types, ensure the project is on schedule, and manage any issues that arise.

Like with traditional tilt-up concrete walls and precast concrete wall panels, roles on the construction site can overlap, or be divided amongst more people depending on the size and budget of the project.

### Equipment – Quantity, and Type

3D printed concrete walls require specialized equipment and resources. Below is a general list of equipment that may be necessary for the manufacturing and installation of 3D printed concrete walls.

- 3D concrete printer – The most crucial piece of equipment needed to make 3D printed concrete walls is, of course, the 3D concrete printer. This machine is designed to extrude a specially formulated concrete mixture and can be gantry-based - working within a fixed rectangular shape - or robotic arm-based where it has more flexibility but is less precise.

- Software – The appropriate type of software is necessary in both designing the 3D model and translating the design into readable instructions for the 3D printer. Autodesk software such as REVIT or other BIM softwares may be used. BIM stands for Building Information Modeling. This software can play an important role in the planning, designing, and construction processes.
- Support Framing – Temporary support framework may be necessary depending on the design of the structure. The support framework is removed upon structure or section completion.

### Speed and Efficiency

The implementation of 3D concrete printer on a construction site can potentially have a significant impact on site efficiency. This technology can reduce the amount of material waste produced during construction, as it only uses the exact amount of concrete necessary for the design. Additionally, it can free workers to complete other tasks.

While 3D concrete printing is not the speediest method of erecting a structure, as the technology is developed and refined it has the potential to completely change the speed at which large structures are completed. Recently, there has been small houses successfully 3D printed in as little as 24 hours. Also, whereas construction workers often cannot work at night, many 3D concrete printers can be utilized at any hour of the day, although the construction process may still be halted by weather and other factors.

### Sustainability

Environmental impact and sustainability are two places where 3D printing in construction really shines. Even still, there are both positive and negative impacts. For example, 3D concrete printing can minimize waste by maximizing material efficiency. When 3D concrete printing it is easy to avoid using excess concrete by using only the exact amount that is needed. This is a vast improvement compared to traditional construction methods where waste is often prevalent. 3D printed concrete can also utilize recycled materials and waste materials from other industries, such as crushed concrete from demolished buildings, which can reduce the environmental impact of new construction and development. There are projects in progress that have successfully used “green concrete” in 3D concrete printing which replaces much of the cement in the concrete ink with byproducts from other industries. This helps to alleviate some of the negative environmental impacts associated with the products of cement such as the high carbon emissions.

The overall environmental impact of 3D concrete printing is still being assessed as it is a relatively new technology. Alternatives to traditional cement in the concrete formula are actively being explored and can only be tested with further experimentation and research.

### Conclusion

As of right now, precast concrete wall panels, traditional tilt-up concrete wall panels, and 3D printed concrete walls all have their place in the construction industry. Precast concrete walls and traditional tilt-up concrete wall panels are “tried-and-true” methods of construction that have seen success for decades whereas 3D printed concrete walls are a potential-packed emerging technology. Each method of concrete wall construction has its own merits, each suited for different circumstances. The choice between these methods depends on factors like project specifics, available resources, local regulations, and the evolving state of 3D printing technology. In an ever-changing industry on an ever-changing world perhaps it is time to embrace 3D printing technology as the tool it is designed to be, or perhaps not.