

THE ULTIMATE GUIDE TO OPTIMIZING LAYOUT FOR STEEL AND CONCRETE



There's already a lot written and discussed about how structures are conceptualized and designed. Likewise, there's plenty of information about how every aspect of a structure is physically erected. But, for those who are not intimately involved in the full construction process, the integral set of steps between those two bookends is largely a mystery. Or, at the very least, its vital role in project success is underappreciated.


Of course, we're talking about construction layout: the project phase in which the architect's, engineer's, and detailers' ideas are first translated into the real world in the form of layout points and lines that are physically marked onsite. The core purpose of layout is to transfer reference points and alignment from detailed drawings to the site to facilitate construction. Without the reference points and subsequent field points supplied by surveyors and layout

professionals, no actual building work can commence, much less succeed.

At the same time, errors made during the layout process can have a snowball effect on the rest of the build, leading to costly RFIs and rework or even potential safety hazards. This further underlines the important role layout plays in an efficient, successful building project.

Various forms of layout are vital to all the trades that need to coordinate their activity during construction:

- ▶ **Surveying and site prep**
- ▶ **Concrete**
- ▶ **Steel**
- ▶ **Mechanical**
- ▶ **Electrical**
- ▶ **Plumbing**
- ▶ **Interior finishes**
- ▶ **Exterior**



In this guide, we'll be focusing on the most effective strategies available to today's layout professionals as they apply to structural steel and concrete. We'll explore layout's place in modern steel and concrete workflows, how layout tools and techniques have evolved, and highlight how today's best layout pros utilize technology to get the job done.

LAYOUT IN THE ERECTION OF STRUCTURAL STEEL AND CONCRETE

Since steel and concrete are often the first trades to arrive onsite after the initial surveying and site prep work has been completed, steel and concrete layout can often involve structural layout tasks along with more detailed point marking within the structure as construction progresses.

WHAT LAYOUT PROFESSIONALS DO

When starting at the bare dirt, surveyors will have established control points, usually starting with some known point like a property corner. These indicators of where key structural geometry will reside are based on the architectural and detailed design drawings. They are established based on measurement and calculation of precise distances and elevations relative to the initial reference points.

Wooden stakes (often called hubs and laths), nails with stamped markers, iron rods, or other durable markers are driven into the ground at key geometric points, such as grid lines and offset points to establish the structure's footprint within the site. All these measurements must be carefully documented and checked against contract documents to ensure easements, setbacks, and property boundaries are within specifications.

To be effective, these markers need to be durable (appropriate for the length of project), understandable (adapted to the needs of the contractors who will be relying on them), and accurate (to the tolerances required, based on the intended use).

Control points must be:

- ▶ **Durable**
- ▶ **Understandable**
- ▶ **Accurate**

When laying out points within a semi-completed or completed structure, the same basic principles apply. Out of necessity, however, layout points are usually marked using chalk or permanent marker directly on concrete or other structural elements as opposed to stakes or rods driven into the ground.



SKILLS REQUIRED FOR EFFECTIVE LAYOUT

As noted above, accuracy is the key requirement for successful construction layout.

Just as a building built on a weak or damaged foundation is bound to crumble, the installation of any wall, pillar, or beam based on inaccurate layout points is bound to suffer one critical error after another.

In most cases, these errors will be discovered immediately as contractors attempt to install building components and find they can't effectively do so. In those cases, the result is an RFI and/or change order which will probably require input from a detailer or even the architect. Depending on how serious the error, it could be a fairly quick fix or it could take a lot of time and effort. Of course, time is money, so every delay eats away at the project's budget, and at every contractor's profit margin.

If materials have been prefabricated based on what turned out to be erroneous measurements or calculations, the delay and cost of rework can escalate even further. Likewise, in some cases, layout errors may not be immediately apparent during the initial steel and concrete erection phases, but may instead impact the MEP work or later phases of construction. In those cases, rework can be even more costly and time-consuming as adjustments need to be made to try to accommodate structural components that are already in place.

And, in a worst-case scenario, layout errors may not be identified or properly prioritized during construction, but may actually weaken or otherwise compromise the finished structure, creating a serious safety hazard for future occupants.

Without a doubt, layout pros need to:

- ▶ **Do everything in their power to anticipate potential errors before and during every layout process**
- ▶ **Rigorously check all their work to confirm its accuracy**
- ▶ **Understand how the points and lines they're laying out will be used by all the various contractors**
- ▶ **Effectively visualize how their layout points and lines translate to a finished structure**

In doing so, layout professionals are in a position to effectively communicate with all parties and ensure everyone involved in a project understands what is required of layout and how the results need to be communicated.



Layout professionals must:

- 1 Anticipate potential errors**
- 2 Rigorously check their work**
- 3 Understand all design intents**
- 4 Communicate effectively**
- 5 Visualize the finished product**

THE MANUAL LAYOUT PROCESS

For ages, layout was a completely manual process. It required at least two people (although large projects would usually involve many more) and a host of tools:

- ▶ **String**
- ▶ **Tape measures**
- ▶ **Levels**
- ▶ **A theodolite and leveling rod**
- ▶ **Plumb bobs**
- ▶ **Combination squares**
- ▶ **Measuring wheels**



What's more, the sometimes highly-complex calculations required were done manually as well. As technology progressed, pocket calculators, laser levels and distance meters, and electronic theodolites all enhanced the process to some degree, but it still maintained a lot of potential for human error.

The introduction of the first electronic total stations in the early 70's was another step

in the right direction, as were the advances in CAD as they related to the generation of layout points and verification of point placement accuracy. But, there was still room for improvement.

Today, layout professionals working in steel and concrete have an incredible array of tools and associated techniques at their disposal that pros from the past would envy.

A BETTER WAY TO HANDLE LAYOUT

As we've already discussed, accuracy is paramount in construction layout. At the same time, speed and efficiency are important too. After all, layout can constitute as much as 25 percent of a given contractor's costs. So, the ultimate layout solutions and strategies will combine speed, efficiency, and accuracy at the highest levels.

Let's look into what tools and techniques are available keeping those three factors in mind.



The ultimate layout solutions will offer:

- ▶ **Speed**
- ▶ **Efficiency**
- ▶ **Accuracy**

THE TOOLS



Layout hardware

The advent of the **Robotic Total Station (RTS)** has dramatically enhanced construction layout in recent years. Taking a natural step beyond the capabilities of the electronic total stations of previous decades, an RTS reduces the opportunity for human error and frees up layout pros for other high priority work. It can be controlled remotely via a mobile tablet or controller, allowing just one person to handle even the most complex layout tasks.

MANUAL LAYOUT VS. THE RTS



Watch this head-to-head competition between two seasoned pros handling layout manually and one working with a robotic total station.

The RTS offers both speed and efficiency, with many contractors experiencing huge increases in productivity. In one head-to-head competition, one person and an RTS laid out 200 points in four hours while two people working manually only laid out 97. Importantly, that speed and volume isn't obtained by sacrificing accuracy. In that same competition, the RTS produced no errors while the manual team had to handle two RFI's after they finished, were missing numerous dimensions from the plans, and had a serious layout bust for a mirrored "similar" floor plan.

Similar in function and benefit to the RTS are laser-based rapid positioning tools (RPT) and GNSS receivers that allow steel and concrete contractors to choose the features and tolerances required for a given project.

The most advanced modern RTS models not only handle the necessary measurements and calculations on the fly, they also provide powerful visualization tools, such as photographic documentation and augmented reality-style overlays. They also coordinate directly with powerful layout software solutions for true field-to-office connectivity.



Layout software

Going far beyond the paper drawings layout professionals needed to carry with them, today's layout pro relies on cutting edge software that seamlessly integrates the layout process into the overall construction workflow via Building Information Modeling (BIM).

These programs provide layout pros with access to the 3D models created by designers and detailers — along with all the corresponding metadata — so there's no possibility of misunderstandings. Then, as layout progresses, information can be fed back into the model and updated in near real-time so all project stakeholders are kept informed.



Layout software (cont.)

If changes need to be made, layout can adjust on the fly to avoid costly rework of their own. The resulting data gathered by connected equipment onsite can easily be viewed in context by all other stakeholders for purposes of clash detection, fabrication, and more.

Once again, speed, efficiency, and accuracy are held to the highest standards as every phase of construction remains connected through powerful hardware and software solutions being used to complete the layout.



TOOLS MAKE LAYOUT EVEN BETTER

Earlier, we listed five skills every successful layout professional need to have. With the best tools in hand, all five of those skills are enhanced:

- Incorporating layout points into a BIM model makes it easier for detailers and layout pros to anticipate potential errors.
- Along with eliminating opportunities for human error, the connection between the RTS, layout software, and constructible model helps the layout pro rigorously check their work.
- Access to the BIM model helps a layout professional understand all design intents.
- The data collected by field equipment and the “common language” of the 3D model allows a layout professional to communicate effectively with all stakeholders.
- Working in 3D naturally enhances the layout pro’s ability to visualize the finished product.

THE TECHNIQUES

By taking full advantage of the tools described above, skilled layout professionals can enhance their treatment of all the following layout tasks and more:

- ▶ **Footings, Foundations, and Stem Walls:** Checking the placement of formwork, steps, block outs, anchor bolts and more, before, during, and after the pouring of concrete. Even variations as slight as $\frac{1}{8}$ of an inch in any of these components can be instantly identified and corrected while the concrete is still wet:
 - **Anchor Bolts**
 - **Drilled Piers, Offsets, Pier Caps**
 - **Shoring Walls & One-Sided Forms**
 - **Corners, Edges, Steps**
 - **Door Block Outs & Brick Ledges**
 - **Embed Plates & Inserts**
 - **Rebar Clearances & Cages**
 - **Precast Placement Dowels**

- ▶ **Steel Erection:** Steel contractors not only have to layout their specific items, but also need to check concrete work to make sure all attachment points are correct:
 - **Anchor Bolts & Shim Heights**
 - **Embed & Knife Plates**
 - **Edge Angles & Openings**
 - **Pre & Post-Pour Camber**
 - **Stairs Connections**
 - **Sleeves & Handrails**
 - **Columns**



- ▶ **Super Structure – Concrete Cores & Slabs:** Verifying placement and alignment of all openings and components embedded in the concrete so expensive rework and dangerous damage down the road can be avoided:
 - **Door Openings, Flip Pockets & Inserts**
 - **Elevator & Stair Attachments**
 - **Embed Plates & Inserts**
 - **Rebar Clearances**
 - **Post-Tensioning Cables**
 - **Sloping Slabs to Drains**
 - **ADA Ramps & Sidewalks**

- ▶ **Slabs on Grade (SOG) or Deck (SOD) - Flatness:** Confirming the flatness of slabs within the tolerances needed for proper load bearing, flooring installation, precision usage, and resistance to damaging weather:
 - **Flooring installation**
 - **Warehouses & Manufacturing**
 - **Rebar & Mesh Clearances to Top of Slab**
 - **Pre & Post Shoring Removal for SOD**
 - **Pre & Post - Post-Tensioning Cables**
 - **Weather related curling or slab heaving**
 - **Moisture curing & ponding (bird baths)**

- ▶ **Super Structure – Precast Concrete and Steel Fabricators:** Performing layout right in the fabrication shop and carrying the data directly to the site with no issues in translation so everyone is clear on:
 - Openings, Attachments, Embeds, Anchors
 - Pre & Post-Pour Camber for Deck Slabs
 - Plumb, Square & Flatness
 - Clips, Angles, Bolt Holes, Stiffeners
 - Complex Assemblies & Curves
 - Pre-Loaded Camber
 - Welding Deformations

Without a doubt, it's an exciting time to be involved in construction layout.

For more information about the most advanced layout solutions available today, visit [Trimble Building's field technology hub](#). To learn how to select the perfect layout solution for your unique needs, download our free guide, [The Tech Behind an Optimal Layout Process](#).

