MACHINE GUIDED CONSTRUCTION

A Surveyors Perspective

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Introduction

The art of surveying has progressed a long way since its ancient Egyptian origins. Early survey tools involving long sections of rope with markings were replaced with chains, compasses and complex mathematical equations, which in turn were replaced with theodolites and eventually total station instruments. Over time, inventions have appeared that have made a surveyor’s job not only easier, but much more accurate.

Today surveyors can utilise GPS satellite technology to determine centimetre accurate positions along with EDM Total Station measurement tools for millimeter accuracy. Additionally, survey software has become more user-friendly and intuitive allowing for efficient and widespread field use, including the integration into construction machines.

Advantages of Machine Control

Pegless Construction

Construction sites and survey pegs have historically gone hand-in-hand. A traditional earthworks operation firstly involves the surveyor building batter rails on both sides of the alignment to define the design edges and batter slopes. Once the bulk material is removed, additional survey pegs are required for the trimming of each alignment. Additional roadway features such as cut benches and drains also require survey pegging.

However, because machine control operators have constant design guidance from within their machines, they no longer require the traditional survey pegs. With design information loaded into the construction machinery, the operator is able to view real-time cut and fill values displayed inside the machine’s cab. Operators are able to view both horizontal and vertical data for every millimetre of the jobsite rather than relying on survey stakes and grade-checkers with string lines and tape measures for guidance.

The operator can switch between plan, cross-section or profile views as required. Vertical offsets can be applied to the design for differing pavement levels. A variety of other information can also be viewed as required, such as the cross-slope of a grader’s blade or the horizontal distance from an excavator’s bucket to the toe of a batter.

The fact that GPS guided plant can operate independently of any survey pegging has significant cost benefits. Less survey pegs means less survey field requirements. The need for grade checkers is eliminated. There is also considerable savings in survey consumables (stakes, ribbon, etc).
Overall, the creation of a pegless construction site eliminating the need for bulk earthworks setout is undoubtedly the biggest advantage of the use of machine control over traditional forms of construction.

Machine control equipment can now eliminate all the old tools from the construction site. With constant design reference for every millimetre of the job, machine guidance enables more accurate construction than traditional survey methods.

The accuracy of the machine control systems ensures grades that are within tolerance every time. Rookie machine control operators are able to use the system to continuously check the constructed results. More experienced operators are able to achieve accuracy on the first pass.

Machine guided construction eliminates the requirement for mid job survey works such as replacing missing and disturbed stake setout. It also results in faster survey quality-assurance checks as there is rarely the need to trim off any high spots. Thus earthworks construction projects using machine guidance experience fewer errors and greater conformance.

Improved Accuracy

Earthworks is a game of cubic meter volumes and heavy machinery. The challenge of moving earth to tolerances of millimetres is daunting to say the least. For years, mankind has managed this process with rudimentary tools like sticks and strings. This system sometimes works well but is always time consuming.

Errors are common due to leaning and disturbed pegs, slack stringlines, misread tape measures and “eying in” information between the pegged cross-sections. Therefore, when a surveyor used to show up to check final results, there was little guarantee that the results would be within tolerance.
Design Updates

Traditionally, a design change made during the progress of a project results in any survey field setout being inaccurate until the survey crews identify the changes and then became available to re-mark (or completely remove) them. This is obviously not an instantaneous process. Consequently, there is a real risk of an intended design change being missed in the field.

With the use of machine guidance in replacement of survey pegs, the design changes are electronically updated into the system. Design changes can be quickly and easily distributed to the machine for instant use. Similarly, superseded designs can be removed from the machine in the same manner, ensuring that only current information is available in the field.

Thus the timely exercise of surveyors needing to remove and replace setout stakes in order to reflect design model changes can be eliminated using machine guidance technologies.

Unplanned Works

It is a reality of construction that work does not always proceed as planned. Unpredicted delays often result in the need to move earthworks activities at the last moment. Traditionally, this involved waiting for rushed survey setout in the new work area, which in turn impacts on the survey works planned for the day.

With the use of machine guidance, all of the design information is available in the field meaning there is no need to wait for survey. Field crews have the ability to commence (if not complete) unplanned works without the need to wait for traditional survey setout.

Additionally, because machine control operators have access to all of the design information, the extents of the job are readily available without the need for traditional survey setout. This enables better planning of such things as stockpiling and also assists the positioning of basic site infrastructure such as haul roads, site compound locations and temporary drainage.

Thus the use of machine guidance reduces machine and field downtime. It also assists the efficient use of survey resources as there is little need for rushed setout due to unplanned works.

Increased Safety

Construction sites are always hives of activity. Earth is moved using heavy machinery including repeated rounds of scraper fleets and/or road trucks. Construction programming is continuously tightening and this pressure results in multiple operations being conducted in the same work area. The work areas themselves are often difficult to access within relatively confined spaces. There is an obvious safety concern with surveyors walking around in such conditions.
As using machine guidance reduces the need for on-the-ground survey set out and construction crew string lining, there is less opportunity for workplace injuries involved with these tasks. This includes the typical manual labour injuries associated with using sledgehammers and stringlines. This also includes the particular safety concerns that are specific to construction sites including confined work spaces and large quantities of heavy vehicle movements.

Above: Traditional construction involving grade checking behind the grader.

Above: Machine guided construction without the need for grade checkers. Two graders work side by side, each guided by its own total station which is transferring millimetre levels to the blade for final trim work.

In a traditional pavement trimming operation, grade checkers work behind the trim grader by running a string line between the survey stakes and using a tape measure to dip the required distance. They will use spray paint to advise the grader operator of the current level for the graders next pass. Hopefully, they will be out of the way before the grader pulls into reverse. With machine guidance construction, real-time levels are displayed to the operator inside the cab. There is no need for grade checkers, string lines or survey stakes.

Clearly this scenario demonstrates a safer construction method than traditional construction methods.

Using machine guidance in bulk earthworks operations and pavement trim operations is unquestionably safer than traditional survey methods.

Increased Job Satisfaction

From a surveyor’s point of view, there is also an often-overlooked advantage of using machine guidance on construction sites. As survey crews are performing less of the manual and repetitive task of pegging, they are able to move on to more satisfying tasks. This is particularly true of work sites and areas that for whatever reason require the repeated setout of the same roadway features. Continually pegging the same thing in the same area can become soul-destroying. However, with the use of machine control, bulk earthworks setout is not required and the field crews always have instant access to the required information.

Similarly, another somewhat unexpected benefit of using machine guidance is the closer working relationship between field crews and surveyors. Traditionally in the Australian construction environment, surveyors do not get involved with any earthworks planning; they are largely removed from the earthworks operation and responsible purely for setting out the intended design and then checking completed works against the design.
However, by integrating the survey systems and the construction equipment, the two groups have been forced to work closer together which has helped open up communications between crews.

Hence the use of machine guidance has helped increase job satisfaction by removing the need for pegging and helping to integrate the survey and construction teams. Consequently, the use of machine control has contributed to a reduction in project staff turnover.

**Challenges of Machine Control**

As we have seen there are numerous advantages in using machine guidance over more traditional survey methods. However, like any new method there are also a number of challenges to overcome.

**Field Reference**

While the move to a pegless site certainly helps streamline the survey operations of a project, it does pose a significant challenge to the supervisors responsible for overseeing on site operations.

With no survey marks to reference, field supervisors and client inspectors are effectively working in the dark – struggling to visualise what they are trying to build. In fact, instead of the supervisors, the actual machine operators now have all the design information at their fingertips.

The solution to this challenge is to install GPS devices into the site supervisor vehicles. Earthworks foreman and leading hands are constantly driving up and down their work areas. With GPS displays mounted onto the windscreen of their vehicle, these field supervisors are given real-time access to both basic cut/fill levels as well as cross-section and long-section information for every millimeter of the construction.

With just some basic system training, field supervisors and client inspectors are empowered with the information they require to both visualise the job and check on the progress of the equipment under their supervision. GPS Supervisor Kits are the perfect supplement to machine control plant. The supervisor systems effectively solve the challenge of providing field reference in a pegless site.
Operator Training

Like any new system, the adoption of machine guided construction involves the significant challenge of operator training. Machine operators capable of their traditional role are required to learn a new method, albeit a user-friendly system.

The implementation of machine control technology onto a construction project is often initially met with resistance. However, it does not take long for those involved to realise the benefits of machine guided construction and shortly most are embracing the challenge.

This being said, it can be necessary to employ the services of a suitable person with advanced knowledge of the capabilities of the machine guidance systems in order to maximise operator efficiency, particularly on larger projects that employ numerous operators unfamiliar with 3D guidance.

Reliance on Machine Control

As the jobsite progresses and the full benefits of machine guidance are realised, the field operations become very reliant on this system.

The process often goes full circle – from field supervisors wanting pegs to check the accuracy of machine guidance to field supervisors wanting the machine guidance to check the accuracy of the pegs! With 3D guidance replacing all traditional earthworks setout, the job progress becomes quite reliant on the machine control systems.

In this way, it is important to provide good support for machine control. This includes regular system checks as well as experienced troubleshooting support. Again, it is important to have access to a suitably qualified person willing to embrace the machine control support role in order to ensure that the systems run efficiently and effectively. Similarly, it is wise to have good supplier relationships to ensure that hardware support is readily available.

Limited Use of Machine Control

Machine guidance technologies are currently largely limited to earthworks machines. The numerous benefits of machine guided construction cannot easily be applied to the construction of bridges and culverts, which must still be surveyed in traditional manners.

Advancements are being made in the development of machines that can use 3D guidance in other construction processes. Machine guided kerb and channel machines / barrier machines have recently become available for use as has 3D-guided pavers and trimmers. Developments are in their infancy for machine-guided concrete screeds and the like. Continued feedback and support of machine guidance technologies can aid in the enhancement of machine guided construction.

The possibilities for increased construction efficiencies are almost endless and embracing these technologies will almost surely reward the user with significant cost and productivity savings.

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