GPS Applications in Civil Engineering

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Civil engineering works are often done in a complex and unfriendly environment, making it difficult for personnel to operate efficiently. Being able to provide a high accuracy positioning in a cost effective manner, GPS has found its way into the civil engineering industry, replacing the conventional methods in most of the cases. With GPS, machineries are being automatically guided and controlled. This is especially useful in hazardous areas, where human lives are being endangered. For those situations where the GPS signal is obstructed, such as in open pit mines, GPS has been successfully integrated with conventional equipment. A number of integrated systems have been successfully developed, including GPS/Total Stations, GPS/Lasers, and GPS/Inertial Navigation Systems (INS). INS is a relatively environment independent system consisting mainly of accelerometers and gyroscopes, which can be used for autonomous positioning and attitude determination. This article shows how GPS can be used in the various civil engineering applications.

GPS for Construction Industry

The ability of GPS to provide real-time sub-metre and centimetre level accuracy has significantly changed the construction industry. Construction firms are using GPS in many applications such as road construction and earth moving, fleet management and other civil engineering applications (see Figure 1).

In road construction and earth moving, GPS, combined with wireless communication and computer systems, is installed on board the earth-moving machine. Designed surface information, in a digital format, is uploaded into the system. With the help of the computer display and the real-time GPS position information, the operator can view whether the correct grade has been reached. In situations when millimetre-level elevation is needed, GPS can be integrated with rotated beam lasers.

The same technology (i.e. combined GPS, wireless communications and computers) is also used for foundation works (e.g. pile positioning) and precise structural placement (e.g. prefabricated bridge sections and coastal structures). In these applications, the operators will be guided through an on-board computer display, eliminating the need for the old conventional methods.

GPS is also used to track the location and usage of the equipment at different sites. By sending this information to a central location, the contractors would be able to deploy their equipment more efficiently.

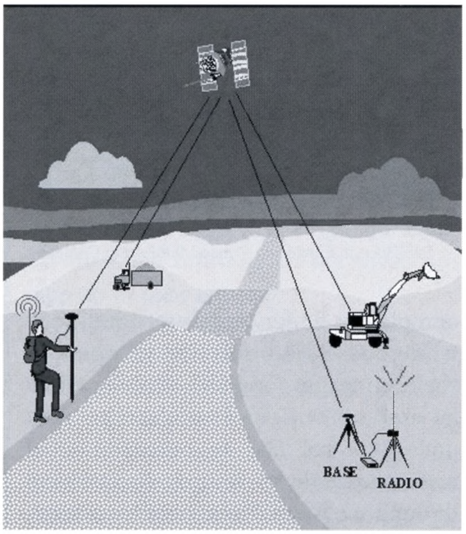

Figure 1.
GPS for Construction Applications

Moreover, vehicle operators can be guided to their destinations. In fact, some products are on the market today to specifically serve the asset tracking needs of fleet management operators, for example the Magellan Asset Vision™ system (Figure 2). Asset Vision is a mobile communication and tracking unit featuring GPS and cellular technology in a black box that offers a complete solution with its own data and unit management software. It can track and monitor engine diagnostics, front and rear attachment hours, equipment location, and several other user defined parameters.

GPS for Mining and Tunnelling Surveys

Until recently, conventional surveying was the only method available for staking drill patterns and other mining surveying. As a result of the harsh mining environment, however, stakes were often buried or displaced. In addition, drill operators had no precise way of determining the actual bit depth. Likewise, there was no way of monitoring the drill performance in the various geological layers or monitoring the haul trucks in an efficient way. More recently, however, the development of the modern positioning systems and techniques, particularly the real-time kinematic GPS, has dramatically improved the various mining operations. In open-pit mines, for example, the use of real-time kinematic (RTK) GPS has significantly improved several mining operations such as drilling, shoveling, vehicle tracking and surveying. RTK GPS provides centimeter-level positioning accuracy, and requires only one base receiver to support any number of rovers. As the pit deepens, however, part of the GPS signal may be blocked by the steep walls of the mine causing a positioning problem. This problem, however, has been successfully overcome by integrating GPS with other positioning systems, mainly the pseudolite system.

The mining cycle includes several phases, with the ore excavation being one of the most important phases. Excavating the ore is made by drilling a pre-defined pattern of blast holes, which are then loaded with explosive charges. The pattern of blast holes is designed in such a way that it optimizes the size of the rock fragmentation. As such, it is important that the drills be precisely positioned over the blast holes, or otherwise re-drilling may be required. An efficient way of guiding the drills is through integrating GPS with drill

Figure 2.
Magellan Asset Vision System

navigation and a monitoring system consisting of an on-board computer and drilling software. Some systems utilize two GPS receivers, mounted on the top of the drill mast, for precise real-time position and orientation of the drill. The designed drill pattern is sent to the on-board computer via radio link, which is then used by the integrated system to guide the drill operator to precisely position the drill over blast holes (see Figure 3). This is done automatically without staking out. In addition, the on-board computer displays other information such as the location and depth of each drill hole. This is very important for the operator to view whether or not the target depth has been reached. As well, the system accumulates information on the rock hardness and the drill productivity, which can be sent to the engineering office in near real-time via radio link. Such information can be used not only in monitoring the drill productivity from the engineering office, but also in understanding the rock properties, which could be used for better future planning.

GPS is also used for centimeter-level accuracy guidance of shoveling operations (Figure 3). Shovels are used in loading the ore into the haul trucks, which then transport it and unload it in stockpiles. With an integrated GPS and shovel guidance and monitoring system, elevation control can be automated. With the help of the system display, shovel operators will be able to keep the correct grade. This is done automatically without the need for grade control by conventional surveying methods. Similar to the drilling, shoveling productivity can be sent to the engineering office in near real-time via radio link for monitoring and analysis.

In transporting the ore, haul trucks use continuously changing mining roads and ramps. Unless efficiently routed, safety and traffic problems would be expected, which causes an increase in the truck cycle time. The use of GPS, wireless communication and a computer system on-board the haul trucks solve this problem efficiently. With the help of a computerized dispatch system, haul trucks can be guided to their destination using the best routes. In addition, the dispatch center can collect information on the status of each haul truck as well as the traffic conditions. Analyzing the traffic conditions is particularly important in making more appropriate road design.

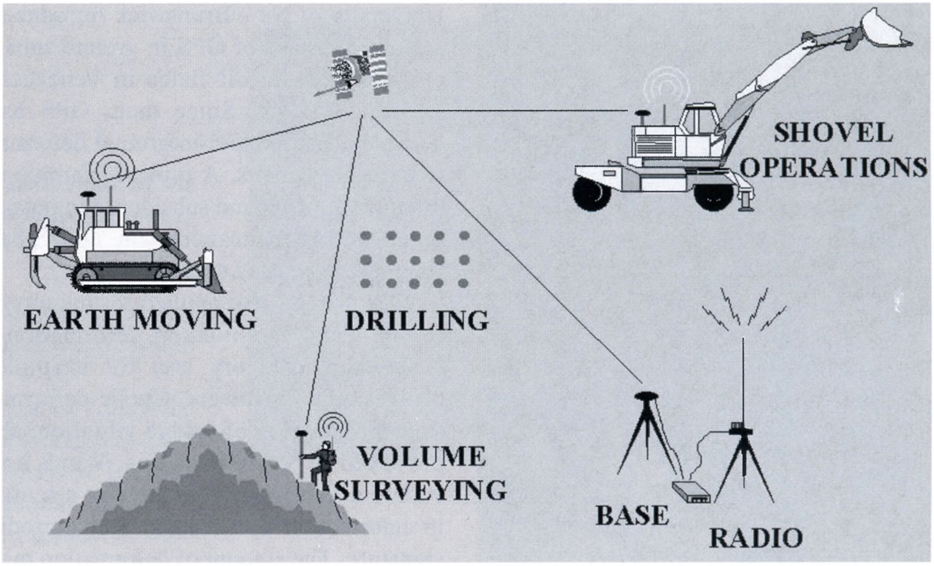

Figure 3. GPS for Open-Pit Mining

GPS is also used in other phases of the mining cycle, for example, checking the coordinates of the individual points and in volume surveying. Either the real-time or the non real-time kinematic GPS could be used for these functions (Figure 3).

GPS for Monitoring Structural and Ground Deformations

Monitoring of structural deformations requires the highest possible accuracy of measurements. Here, one should distinguish between the slow motion deformations such as dam deformations, and cyclic structural deformations produced by effects of fast changing loads, such as bridge vibrations due to changeable traffic loads or TV towers vibrations due to wind gusts. GPS has found many applications in both cases. Here, however, one should give a word of warning to those who overemphasize the use of GPS as a stand-alone tool. Generally, structural deformations, for instance deformation of concrete dams, require millimetre and, sometimes, even sub-millimetre accuracy of displacement monitoring. This is still not achievable with GPS in an economical way. Besides, GPS requires good visibility to the satellites and is susceptible to errors arising from the signals reflected from the structural surfaces (so-called multipath effect). Nevertheless, when combined with other high precision monitoring techniques, GPS becomes a valuable tool in implementing, for example, the recently developed (University of New Brunswick) concept of integrated monitoring schemes. According to the concept, the structural monitoring scheme is divided into three components: (1) local structural monitoring using geotechnical/structural instrumentation (e.g. extensometers, plumb-lines, strainmeters); (2) global structural monitoring using terrestrial geodetic techniques (e.g. electronic total stations and digital levels) for connecting together the structural instrumentation and (3) area monitoring network in which GPS ties together the main points of the global monitoring network and connects them to control points in the stable ground. The concept of the integrated monitoring has recently been implemented at the Eastside reservoir project of the Metropolitan Water District of South California. Three large earthen dams (up to 3.2 km long and 80 m high) are monitored using a number of geotechnical instruments as a local monitoring scheme, several robotic total stations with automatic target recognition creating the global monitoring network, and several continuously working GPS receivers connected to the South California GPS reference system creating the area monitoring network. The picture shows one of the GPS receivers that is used to monitor the integrity of Pacoima dam.

Another application of the high accuracy static GPS surveys is in ground deformation measurements in mining areas. In these applications, GPS is usually combined with terrestrial geodetic surveys providing a connection between the local terrestrial monitoring network and control points established outside the area affected by mining. A research group from the

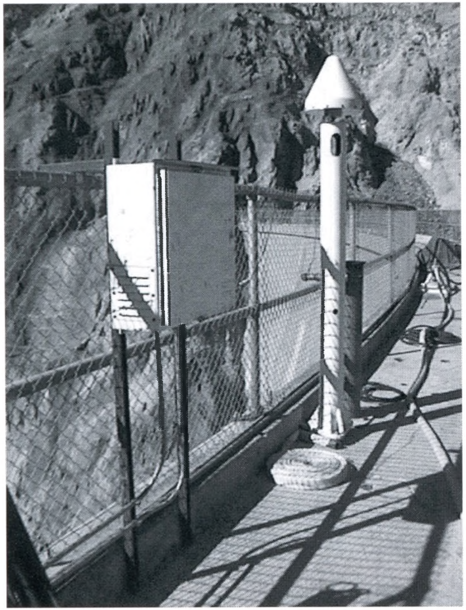

Figure 4. GPS for Measuring Bridge Deformation (Courtesy of Magellan Corporation)

University of New Brunswick introduced a pioneering use of GPS in ground subsidence studies in oil fields in Venezuela already in 1986. Since then, GPS has become a routine tool in ground deformation measurements. A typical example is monitoring of ground subsidence in potash mines in New Brunswick where GPS has routinely been used since 1991.

GPS may be also applied for the monitoring of cyclic structural deformations. Under this category are, for example, bridges and TV towers. Cyclic deformations, in the case of bridge vibration, are provoked by vehicle loading. Winds and variations in temperature are also a source in deformation with seasonal and periodic signature. The amount of deformation may vary with the types of materials used in the construction of the bridge and with its length but it may reach tens of centimetres for a 1 km-long suspended bridge, in its centre. In the case of TV towers the major source is wind gusts. Bridges and towers may be seen as kinematic deforming bodies. Generally, when monitoring structural vibrations, GPS receivers should be located at several points along the monitored structure, particularly at the locations where maximum amplitude of cyclic deformation is expected. For example, in monitoring the world's longest suspension bridge (Akashi bridge, Japan), a GPS receiver is installed at the mid-point of the bridge while two others are installed at the main towers. Figure 4 shows another example in which the Ashtech Z12™ dual-frequency receiver is used for monitoring the bridge deformation. As GPS data collection rate is currently limited to 10 Hz, an INS system may supplement the GPS system, in some cases, to monitor the high frequency portion of the structure vibration.

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REFERENCE:

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