Establishing a Geodetic Monitoring System for Gotvand Dam

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Key words: geodetic monitoring system, dam monitoring

SUMMARY

Geodetic monitoring is one of the most useful systems for monitoring large structures such as dams, towers, bridges, etc, as they can give nearly continuous data about structures' displacements. In these systems positioning sensors such as robotic total stations, GPS receivers, tilt meters, etc are used in a computer network basis so that measurements are carried out automatically in predefined intervals, collected in a database, processed, analyzed and sent to wherever needed.

In Gotvand dam, over Karun River in Iran, one of the most thorough geodetic monitoring systems is being conducted. In this system two robotic total stations (TPS) are located on upstream and downstream side to monitor points on the dam, meanwhile four double frequency GPS/GLONASS receivers defining a GPS network are arranged so that two of them are co-located with TPS's to give their positions with respect to the other two that are located in stable area around the dam.

Along with this configuration, six single frequency GPS receivers with 360 degrees reflectors beneath them are going to be installed on the dam crest to have double measurements from both TPS's in order to adjust the whole network. In this paper we are going to present this system and finally have an assessment on its results.

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1. Introduction

Gotvand dam is a rock-fill dam with clay core which is located in Khuzestan Province, Iran. Being constructed on Karun River with the crest length and height from foundation of 760 and 178 meters respectively, it is the last dam on Karun, which means that there are no more dams on downstream.

Geodetic monitoring of this large dam is somehow very important. Some of the main reasons that forced the client to make this decision are:

1) There are many cities, cultivated lands and residents on downstream side.
2) Total construction cost of the dam and its substructures is estimated about 2 billion dollars which makes it the most costly construction project in the country.
3) There are areas around the dam with potential risk of landslide.

Because of above reasons, Iran Water and Power Resources Company (Client) decided to establish a geodetic monitoring system on the dam which should be able to detect displacements with accuracy of 7mm and Mahab Ghodss Consulting Engineering Company was elected to design and establish the system. It is estimated that the total cost of the monitoring project is about half a million dollar. In the following sections we are going to explain the design aspects, installation and data assessment of the system

2. Design and installation

There are three main phases in installation of any geodetic monitoring system, which are:

2.1. Observation network
2.2. Communication network
2.3. Power supply

Of course the installation order is reverse which means that phases should be done from 2.3 to 2.1.

It should be mentioned that in any geodetic monitoring system there is a software which is in charge of sending commands to sensors, getting data, processing and analysis of the results.

2.1. Observation network

The general scheme of observation network of Gotvand geodetic monitoring system is shown in a map of the dam area and all sites and observation scheme in figure 1.

As shown in figure 1, TPSL and TPSR are robotic total stations (TPS) which are in charge of observing reflectors located on the dam face upstream and downstream and sending measured data through the communication network to the software located in control room.

Two Double frequency GPS/GLONASS receivers are co-located with TPS's which are intended to give absolute coordinate to them with respect to a reference stable area, so two other double frequency GPS/GLONASS receivers named GPSL and GPSR are installed in order to define a GPS network.

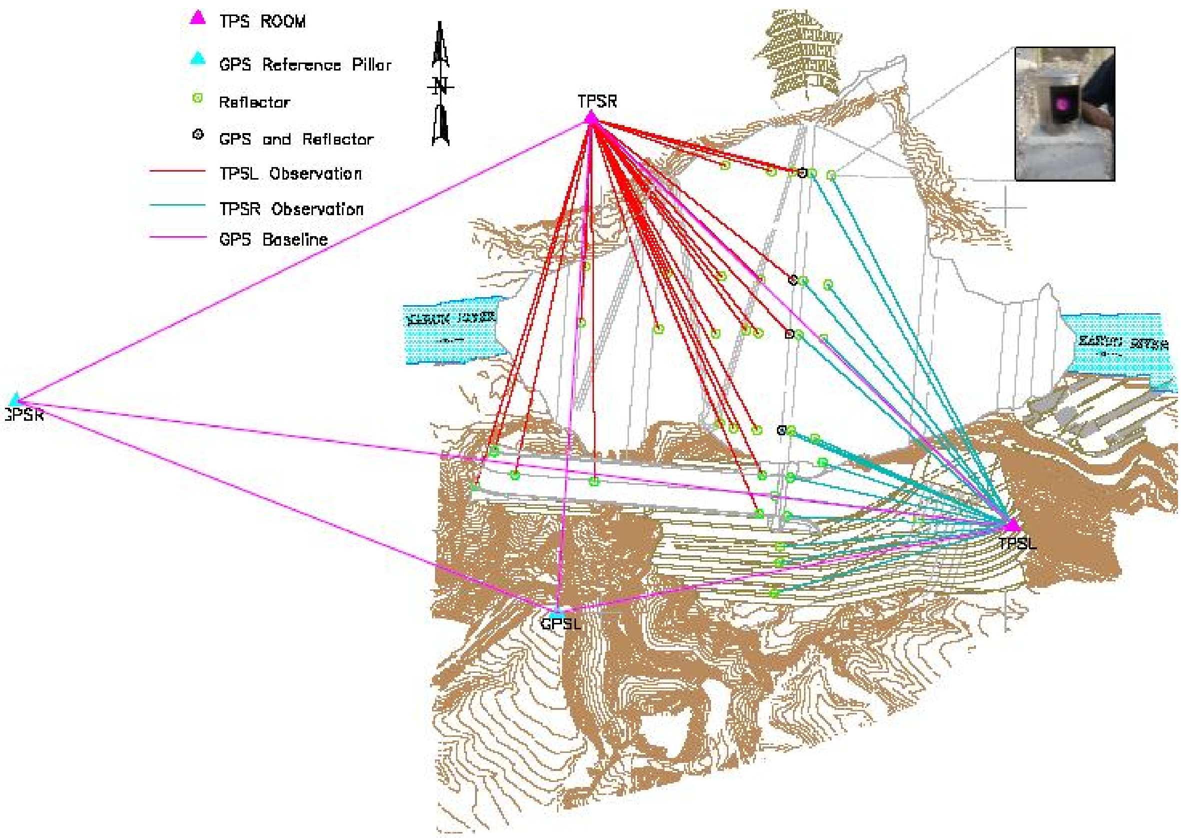

Figure 1- Map of Gotvand dam (under construction) along with and GPS and TPS sites

The reference stable area is near the dam but far from its pressure influences. For example GPSL is about 100 meters above TPSL and TPSR is more than a kilometer far from the dam body.

In order to apply PPM corrections to distances observed by TPS's, two meteorological sensors are installed in TPSL and TPSR sites and their data are also sent to the software automatically.

In table 1 all four sites and their sensors are listed:

Sensors \ Sites	GPSL	GPSR	TPSL	TPSR
Double frequency GPS/GLONASS receiver	✓	✓	✓	✓
Robotic Total Station			✓	✓
Meteorological sensor			✓	✓

Table 1: List of four observation sites of Gotvand geodetic monitoring project and their sensor type

In the following, some design considerations of site selection criteria in Gotvand geodetic monitoring project are explained:

- TPSL and TPSR should have as much view on the dam and its substructures as possible. It is preferred that they are on a stable area but is not necessary because they are co-located with GPS/GLONASS antennae and we can have their displacements in a GPS network. It is also recommended that these locations have good sky view for GPS/GLONASS satellites, especially towards South. This condition in Gotvand dam for TPSL was not fulfilled because of a very high cliff near the site, so it was decided to compromise it by using double frequency GPS/GLONASS receivers to supply as much observations as possible. In figure 2 the location of TPSR site along with its sensors and other equipments is shown.

Figure 2: location of TPSR site with its sensors, GPS/GLONASS antenna on top of the room and TPS inside the room on the pillar

- GPSR and GPSL should be on stable areas from geological and geotechnical point of view as they are reference for whole system. Some studies carried out to fulfill this requirement and two locations were selected. They should have good sky view to receive more satellites, so points of high altitude are preferred. GPS network of all sites should have good configuration from geodetic first order design aspect. Roughly speaking its shape should resemble a square as much as possible. In figure 3 the location of GPSR site along is shown.

Figure 3: location of GPSR site, GPS/GLONASS antenna on top of the pillar

- The instruments are kept in special designed rooms which are equipped with valuable devices and accessories, so the sites should be selected in a way that highest possible security is provided.

  In Gotvand dam, Leica geosystems sensors were used which are especially designed for geodetic monitoring applications. In table 2 some of these instruments with their specifications are listed:

Sensor name	Sensor type	Number of instrument used	Nominal accuracy
TM30	Robotic Total Station	2	0.5 arc second for angle 0.6mm+1ppm for distance
GMX901	Single frequency GPS Receiver	6	Variable (good condition mm)
GMX902 GG	double frequency GPS/GLONASS Receiver	4	Variable (good condition sub-mm)
DTM	Meteorological sensor	2	1 degrees Celsius

Table 2: some of instruments used in Gotvand dam with their specifications

2.2. Communication network

As mentioned before, all data from instruments are brought to the control room through communication network, and commands from software are sent to the sensors. So communication network is the basis that the whole system's work depends on its good functionality.

Data type of the monitoring system are almost telemetry and do not occupy much bandwidth of a communication network so we don't need very high bandwidth links. On the other hand all sites are far from control room (around 2 km) except TPSR which is near, so the system should be able to send and receive data in this range.

Some design considerations for this part are listed below:

- Since construction is active in dam area any kind of cable or fiber optic works is not possible in case it is damaged by machinery.
- Wireless network is very suitable for this area because there is less possibility of damage or signal loss.

So from each site a wireless Netronics Netlink 5x10 was established to the control room. Maximum bandwidth of each link pair is 10 Mbps and they support ranges up to 20 km.

In order to convert RS232 connector of observation sensors to RJ45 LAN, some MOXA NPORT 5410 and 5110 were used which all are for industrial purposes.

In figure 4 some of these equipments installed in TPSL site are shown.

Figure 4: some of the communication network equipments of TPSL site inside a rack

2.3. Power supply

There were two possibilities for power supply in Gotvand monitoring project:

1. Solar panels
2. Urban electricity

Solar panel is very suitable for monitoring projects but in Gotvand dam which temperature goes up to 55 degrees Celsius, using air conditioner for the instrument rooms is inevitable, and since most solar panels do not support that much electric power, this solution was rejected at first. On the other hand because of active construction in all parts of dam area, urban electricity is accessible, so it was decided to use second option for all sites.The problem with all urban electricity is unpredictable cut off which also happens in Gotvand dam. So UPS equipments were used to overcome this problem. Each UPS set (Faratel SDC 1500VA) consists of a control unit with four 100 AmpH batteries and a cabinet to keep them.

3. Software

The software consists of three major parts which all are developed by Leica Geosystems Company.

3.1. Spider which is in charge of gathering data from each GPS Receivers, Calculating coordinate of each rover sites (TPSL and TPSR) from a reference (GPSL or GPSR) and sending the results to another software or user. You can easily define each site and related baselines, time interval for post processing and all processing parameters in the software.

3.2. Geomos Monitor which is in charge of processing TPS's and Meteorological sensors data. We must set and orient each TPS's and measure the reflectors for the first time. In this software TPS's coordinates are brought from Spider and observation interval and other parameters are defined. The software automatically send commands to every TPS to directs to its reflectors in predefined intervals and re-measures each point, get data and recalculate the position and displacement. All data are stored in a SQL Server database which gives us this opportunity to write queries to retrieve data or displacements daily, weekly or monthly.

3.3. Geomos Adjustment which gets data processed by Geomos Monitor, adjust network by known control point and give final results. This part of the software is not active in Gotvand dam yet because the dam's crest is not completed.

4. Results

When the system was installed for the first time, it took nearly one and a half month to assess the system's functionality and get reliable data. In this period, the time interval of observation was set to 1 hour for TPS's, half an hour for Meteorological sensors and 12 hours for GPS baseline processing. It can be seen from results (figure 5) that the hourly data is highly variable because of adverse air temperature in the area (sometimes 55 degrees Celsius) and occasionally regional dust. So it was decided to either set the time of observation to nights only or average the results daily, weekly or monthly which the latter proved to have good results.

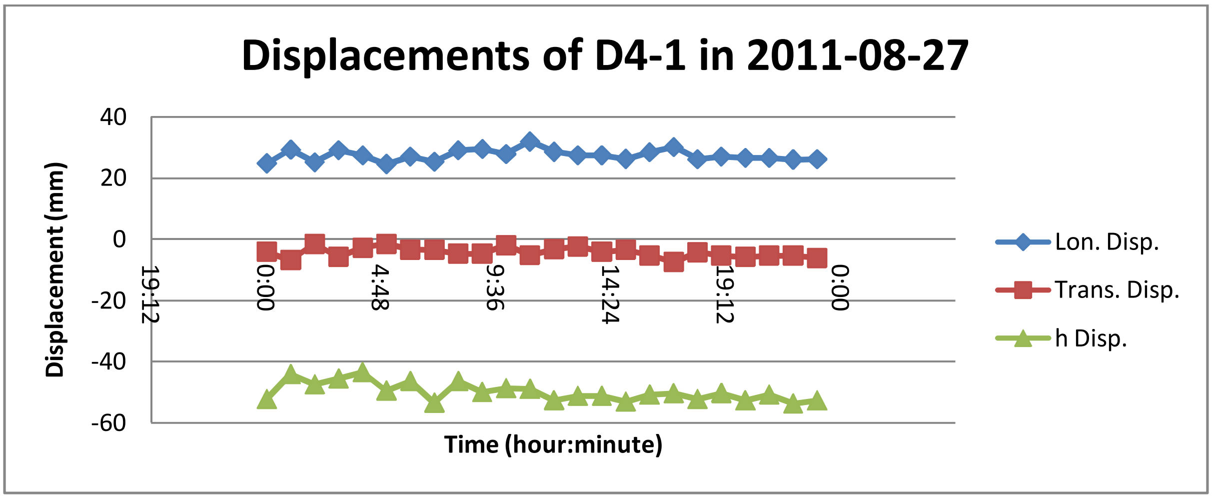

Figure 5: Daily displacements diagram of point D4-1versus time

In figure 6 and 7 displacements and its daily standard deviation is depicted for point D4-1 which is located on upstream side nearly center of the dam. As it is shown, height displacements of the point are decreasing gradually versus time (day of Year) which means that we have settlement in its surrounding. On the other hand longitudinal displacement diagram shows that the point is moving downstream side which is obvious in Rock-fill dams but transverse displacement is not varying much, mainly because of this fact that the dam does not have much movement along its axis.

Convention for axes directions: Transverse is along the crest from left bank to the right and Longitudinal is perpendicular to the transverse axis towards downstream.

In figure 7 we can see that the accuracy of displacements of this point is around 2.5 millimeter in height and 1.5 millimeter in horizontal directions, which is good for D4-1 located 502 meters from TPSL site. Of course this accuracy aggravates in far distant points and increases for near points But satisfies the project requirements.

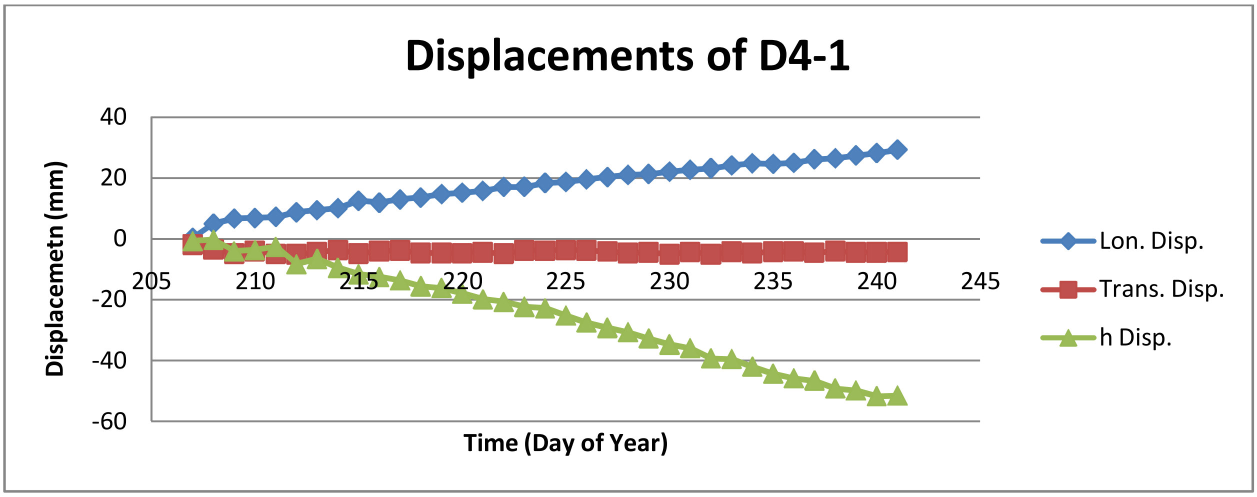

Figure 6: Displacements diagram of point D4-1versus time (Day of Year)

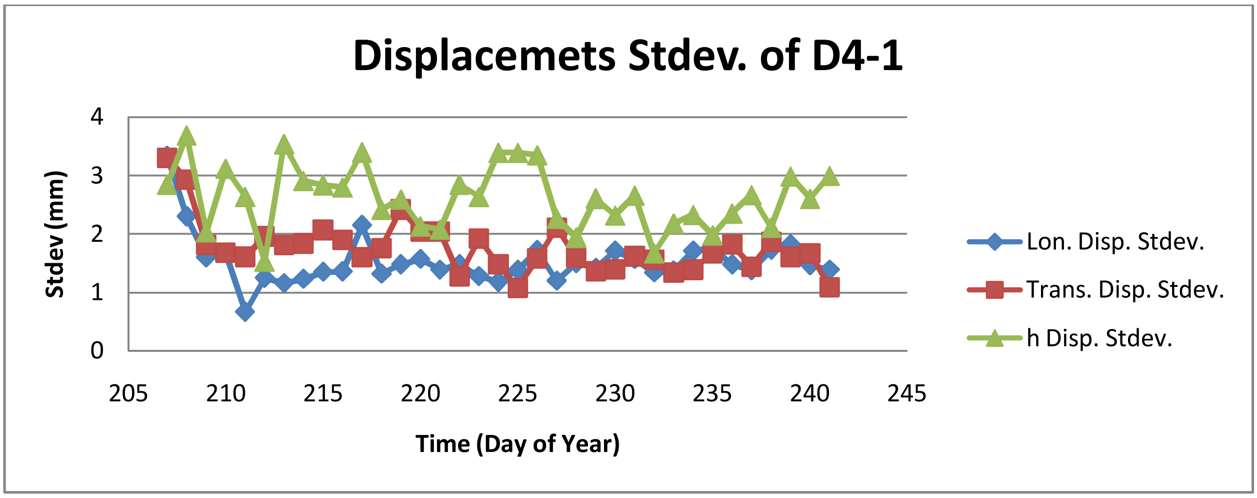

Figure 7: Standard deviation of Displacements diagram of point D4-1versus time (Day of Year)

5. Conclusions and recommendations

Geodetic monitoring system of Gotvand dam is the first comprehensive monitoring systems conducted in Iran. Results of the system have good accuracy to present displacement of the dam and other substructures.

It should be mentioned that as the dam is under construction, monitoring system has not completed yet. 6 single frequency GPS receivers with 360 degrees reflector beneath them should be installed on the dam crest so we can have observations from both TPS's to points along with GPS positioning. This gives the opportunity for adjusting the network which will be done by Geomos adjustment software.

6. References

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