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Monitoring Movement in Barrage Depending on Four Dimensions

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Abstract: The structures with large bloc are exposed to self and external factors affecting on interdependence the parts of the structure between them and its interdependence with surrounded on the other hand. Leading to limited movement in a block structure relative to the surrounding or the parts movement relative to each other. Monitor this movement and measured it in time periods give a clear perception of the administrators on the work of those facilities. In this research was selected one of barrages on the Al-Forat River as a case study. The barrage under study (which is a three parts, the most important part is (barrage) that his job water reserve for the purpose of raising the water level and the other remaining parts are a (head regulators) for the purpose of organizing access water to the city through the two side channels). Epoch monitoring used to find the relative positions of the points at certain period of time and compare this position with the absolute coordinates of these points and the monitoring process is repeated every thirty day for a whole year. The final result shows that the body of the barrage under study fixed and that the movement and crawling limited to embankment on both sides and the process of merge between traditional monitoring and GPS provides an accurate and economical control system for the barrage and should be linked monitoring results for the barrage with time (the dimension of time).

Key words: Monitoring, movement, total station, GPS, dimension of time, Al-Forat

INTRODUCTION

The structures with large bloc are exposed to self and external factors affecting on interdependence the parts of the structure between them and its interdependence with surrounded on the other hand (Anghel *et al*., 2015). Leading to limited movement in a block structure relative to the surrounding or the parts movement relative to each other. Monitor this movement and measured it in time periods give a clear perception of the administrators on the work of those facilities on the extent to which those observed movement within normal limits specified by the designer or may constitute exceeded those limits which requires to take geometric measures to avoid any risk that can happen as a result of the negligence of that movement (Casaca *et al*., 2015; Fergason *et al*., 2015).

To draw a clear picture of the amounts and trends movement of the structure relative to its surroundings and the movement of their parts relative to each other is through the establishment a network of control points on the high specification of stability on and around the structures mass (Omofunmi *et al*., 2017).

Measurements are periodically starts to take primary observation and considered as a reference for comparison with subsequent observations and calculate differences to draw diagrams illustrate the amounts of those differences with the direction, so, as to be capable of giving an idea about any movement occurs in the structure (Gonzalez-Aguilera *et al*., 2008).

The barrage is considered essential and vital installations to the lives of people, so, must be the engineer working in such facilities more knowledgeable and science the behavior of these structures during successive time periods (HCECCC., 2014).

The movement’s appearance on the barrage depends on several factors including water level, temperature, pressure and air, ... , etc. Therefore, it became necessary to link these variables with time and monitored as a one variable knows the behavior of the time (the time dimension).

MATERIALS AND METHDS

Structural monitoring: Monitoring it’s a process to take readings for a set of points on the structural body’s to determine the relative movement of the structure horizontally or vertically or both relative to external control points (outside the body of origin) and then analyze this movement in a vertical (1-D) or horizontal (2-D) or vertical and horizontal (3-D). (Henriques and Casaca, 2001). There are three types of monitoring:

Permanent monitoring: the process for holding cycles of monitoring for long periods and continuously, this type of monitoring requires the presence of devices installed permanently in barrage as well as the required maintenance and calibration of the devices.

Semi-permanent monitoring: its similar largely the permanent monitoring but the only difference there is certain period of time separating between monitoring cycles as it also requires the presence of devices installed permanently in barrage and the calibration procedure its continuously. In these two methods can be discover dangerous and sudden movement at the moment they occurs.

Epoch monitoring: it's use to find the relative positions of the points at certain period of time and compare this position with the absolute coordinates of these points and the monitoring process is repeated after the passage of certain time periods, then a process of analysis and comparison, using the traditional monitoring devices (total station and level) and GPS.

This method is less accurate than the two methods above and movement can find out at the moment of monitoring only (Corps of engineers, 1994; Stewart and Tsakiri, 2001).

Monitoring points network around barrage: The monitoring points network must be at a distance from the barrage required a monitoring it, to detect a movement and the movement in structures are calculated relative to these points.

The monitoring points network must be do not move and should be selected in geologically stable areas and must be a strong in trilateration measurements as well as the possibility of reciprocal observation between points. (Currie, 2010).

The strong in trilateration measurements can be calculated from the following Eq. 1:

$$M = \left(N\text{-}R\right)/N^{*}\sum\left(\sigma^{2}a+\sigma a\ \sigma b+\sigma^{2}b\right) \quad (1)$$

Where:

- N = Number of observed directions-2
- R = The number of engineering requirements that must be provided in the network
- σa = The rate of change in the logarithm of sin angle in triangle corresponding to known side to difference of a one second from sixth decimal number
- σb = The rate of change in the logarithm of sin angle in triangle corresponding to required side to difference of a one second from 6th decimal number (Al-Kurbasy and Salih, 2002)

The value (N-R)/N in general forms describes in Table. 1

Table 1: The value (N-R)/N, (Al-Kurbasy and Salih, 2002)

Form	N	R	(N-R)/N
Simple triangle	4	1	0.75
Quadrilateral with diagonals	10	4	0.6
Polygon triangle with center	10	4	0.6
Quadrant with center	14	5	0.64
Penta with center	18	6	0.67
Polygon number of ribs (L) with center			(3L-3)/(4L-2)

Monitoring points network on barrage: The points on the structure must be related to points around it which have been selected for stability.

After locating points on the body of flood control structure must take into account the refractive index through a monitoring selected reference lines. A good reference line is one which traverses approximately the same atmosphere as is found along the lines to points on the flood control structure and is almost the same length or longer (Corps of Engineers, 1994; Currie, 2010).

Barrage monitoring with traditional surveying (total station and level): (Total station and level) devices can be used in traditional surveying to economically and accurately establish or density project control in due course. Quality control statistics and redundant measurements in networks established by these methods help to ensure reliable results. Traditional survey methods using total station and level devices requires visibility between the observed stations, the survey by using these devices are based on the monitoring of movement in the structure points relative to control point with a commitment to accuracy during the monitoring can achieve precision up sub millimeter (Yoshikazu *et al*., 2009; Scaioni and Wang, 2016).

Barrage monitoring with GPS: Establishing or densification of horizontal and vertical control points with differential carrier-phase based GPS is often cost-effective, faster, more accurate and more reliable than most traditional methods. The quality control statistics and large number of redundant measurements in GPS networks help to ensure viable results (Yang *et al*., 2010). Differential carrier-phase based GPS is particularly attractive for horizontal control surveying as compared with traditional surveys because visibility is not required between adjacent stations and GPS equipment is not limited by optics for its range of operations as are most traditional survey instruments but GPS provides height (h) or height difference (h) in terms of height above or below the WGS 84 reference ellipsoid. These ellipsoid heights (h) are not equivalent to orthometric heights (elevations) which would be obtained from traditional differential leveling. Therefore, users of GPS must using

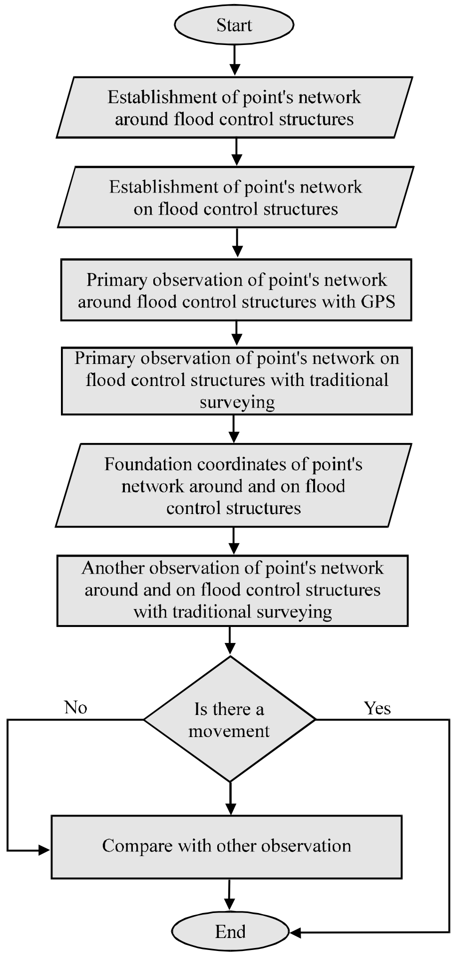


Fig. 1: Methodology

current methodology, (i.e., geoid modeling and transformation software) to use and benefit from them in the traditional surveys (Corps of engineers, 1994; Stewart and Tsakiri, 2001; Hudnut and Behr, 1998).

To draw a clear picture of the amounts and trends of the movement of the structure under study relative to the surroundings and the movement of their parts relative to each other have been followed methodology as shown in Fig. 1.

In this study and for the purpose of conducting calculations and analysis of network control points were used (Arc GIS 9.3, Arc Map, Arc Info) and (Microsoft Excel) programs.

Description barrage under study: The establishment of barrage under study (which is a three parts, the most important part is (barrage) that his job water reserve for the purpose of raising the water level and the other remaining parts are a (head regulators) for the purpose of organizing access water to the city through the two side channels).

Fig. 2: The flood control structure under study

The construction flood control structure under study began in 1984 and became operational in 1986, consists primarily of several structures or parts are:

Barrage:

- The flood control structure body and includes 6 main gates in addition to the parts responsible for processing power and control as in Fig. 2
- Two fish escape: every one of them has a part to prevents the fish go upstream and downstream
- Head regulators: it's used as a control on water discharge.

The importance of studying: Study and evaluation the movement of barrage under study and territories surrounding it and statement the amounts and trends of those movements in four dimensions (X-Z and Time) by mergers traditional survey methods and GPS. Especially, after appearance of cracks in the soil surrounding it and observe the movement in some of joints and cracked edges.

Calculations: Calculations were conducted on all the points (on and around barrage body) have been through three stages.

RESULTS AND DISCUSSION

The first stage; reconnaissance and assigning points around and on barrage under study: The field visit was conducted in 12.29.2011 and see the reality of flood control structure body and territories surrounding it and pointing the variables mentioned above and control assigning points around flood control structure body and its structure as follows:

Distribution (6) control points around the flood control structure body, (4) of which will be main and (2) assist as in Fig. 3 and these point will be considered the

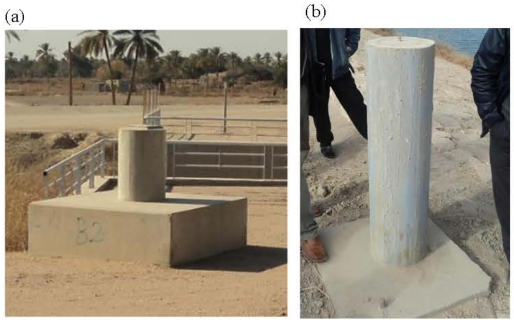


Fig. 3: a) Main control points around the flood control structure and b) Assist control points around the flood control structure

basis for the evaluation of the stability of the region around flood control structure body and a reference for horizontal movement.

Considered (2) points on both sides of the river and outside the mass of Flood control structure body (high point (BM)) as a reference in the calculation of the vertical movement.

Distribution (18) horizontal and vertical control points on both sides of the flood control structure.

The second stage; observed points with (GPS) devices: After the distribution of the monitoring sites of control points around and on the flood control structure body as shown in the Fig. 4.

The monitoring with GPS conducted as the following: Monitoring the network of main control points and both sides of the ground crack in the eastern side of the flood control structure using (GPS) devices type (TPSGRS3) as shown in Fig. 5 and Table 1 and 2.

The coordinates calculated by the global system coordinates the private site of the National Center for Geodetic survey US (NGS OPUS).

The third stage: observed points with (total station and precise level): At this stage will be monitoring the coordinates of the eighteen points located on the barrage body with heights as well as determine the points on the sides of the crack and joints affected in the body that have been observed as follows:

It is monitored vertical and horizontal locations for all the points using the precise level and total station with high precision and a (micro triangulation as shown in Fig. 6 as follows:

- Measure angles with accuracy = 1½, RMS = 1½ and number of observations = 4 Sets for each angle

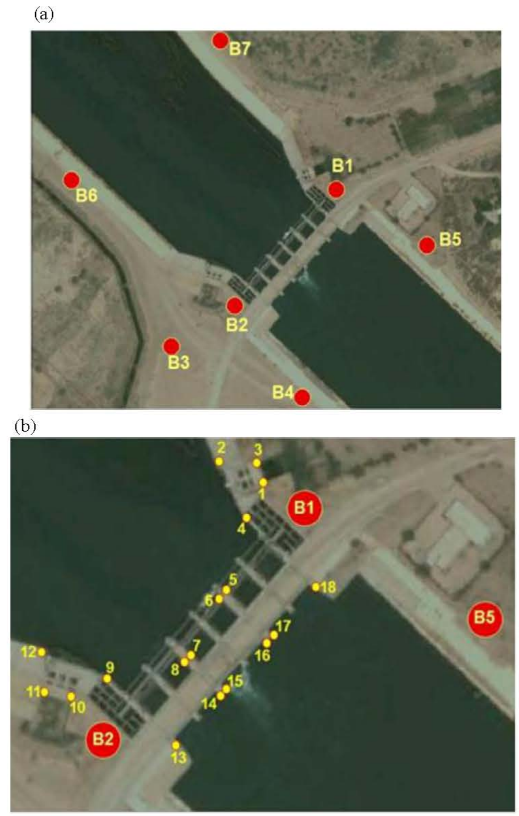


Fig. 4: a) Main control points network and b) Assist control points network

Table 2: Monitoring information using TPSGRS3 (GPS) devices

Monitoring date	Coordinates system	Projection system	Zone	Height system	Accuracy
29/12/2011	WGS 84	UTM	38 N	EGM 2008	1 mm±1 ppm

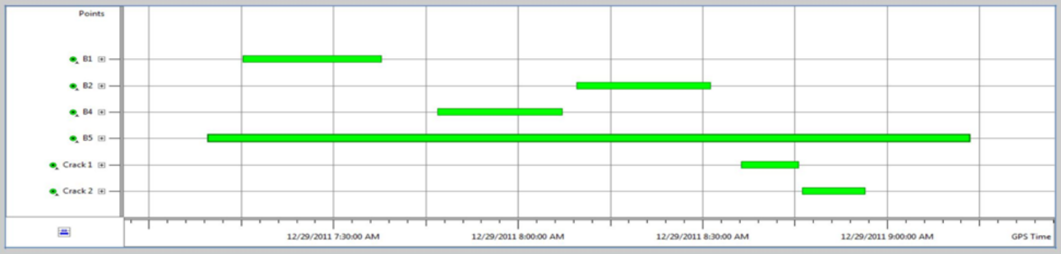
- Accurately measure the distance = (1mm±1ppm)
- The accuracy to measuring elevations using precise level device type (Ziess Ni002) = ±0.002 mm

After complete observed all horizontal points, regarded all these points as one horizontal network using accurate adjustment (horizontal adjustment) and method of (direct observations), apply the same method in calculating altitudes points (vertical network). It has been following the above steps every thirty day for a whole year.

It has been prepared detailed figures to monitor the sites of points showing the amount of movement for each point during the months of March-December (as shown in Table 3-5 and Fig. 7-10 where considered the observation of January 2012 is a 0 observation and in the observation of February which did not shows significant differences.

Fig. 5: Control points on and around the flood control structure body monitored using TPSGRS3 (GPS) devices

Through monitoring the 1st 4 months was observed a simple movement of the right shoulder of barrage not exceed 2 mm to point (B2) and points 10-12 towards the river with a reduction in elevation of



Point Summary Report

Name	WGS84 Latitude	WGS84 Longitude	WGS84 Ell.Height (m)	Grid Easting (m)	Grid Northing (m)	Elevation (m)	Std Dev Hz (m)	Ground Easting (m)	Ground Northing (m)
B1	31°58'58.14388" N	44°34'20.03877"E	23.885	459587.421	3538611.078	27.537	0.001	459587.420	3538611.083
B2	31°58'54.87328" N	44°34'16.55459"E	23.870	459495.587	3538510.739	27.518	0.001	459495.551	3538510.705
B4	31°58'52.78219" N	44°34'18.35082"E	23.326	459542.470	3538446.168	26.976	0.001	459542.453	3538446.109
B5	31°58'56.85006" N	44°34'22.68275"E	23.288	459656.649	3538570.967	26.943	0.000	459656.675	3538570.957
Crack 1	31°58'57.61930" N	44°34'21.02568"E	22.303	459613.256	3538594.824	25.956	0.001	459613.265	3538594.823

Fig. 6: Report of the points monitored by TPSGRS3 (GPS) devices and the duration of each monitoring point

Table 3: Vertical movement of point's observed to the months of March-December 2012

HΔ December	HΔ November	HΔ October	HΔ September	HΔ August	HΔ Julay	HΔ June	HΔ May	HΔ April	HΔ March	Elavtion(0)	Sta.
0	0	0	0	0	0	0	0	-0.002	-0.002	8.53427	1
-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.003	-0.003	5.36223	2
-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.003	-0.003	8.54192	3
0	0	0	0	0	0	0	0	0	0	9.97011	4
0	0	0	0	0	0	0	0	0	0	10.00258	5
0	0	0	0	0	0	0	0	0	0	9.99786	6
0	0	0	0	0	0	0	0	0	0	7.62261	7
0	0	0	0	0	0	0	0	0	0	7.63285	8
0	0	0	0	0	0	0	0	0	0	9.98261	9
-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	8.5712	10
-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	8.551	11
-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	5.39609	12
0	0	0	0	0	0	0	0	0	0	8.58031	13
0	0	0	0	0	0	0	0	0	0	7.57823	14
0	0	0	0	0	0	0	0	0	0	7.57632	15
0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	7.5852	16
0	0	0	0	0	0	0	0	0	0	7.57802	17
0	0	0	0	0	0	0	0	0	0	8.575	18
-0.003	0.001	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.003	10.57232	B1
0	0	0	0	0	0	0	0	0	0	10.57575	B2
0	0	0	0	0	0	0	0	0	0	9.99747	B3
0	0	0	0	0	0	0	0	0	0	10.03706	B4
-0.007	-0.005	-0.003	-0.002	0	0	0	0	0	0	10000	B5
0	0	0	0	0	0	0	0	0	0	7.32272	B6
0	0	0	0	0	0	0	0	0	0	8.76118	B7

Table 4: Horizontal movement in East direction of point's observed to the months of March-December 2012

December-E	November-E	October-E	September-E	August-E	July-E	June-E	May-E	April-E	March-E	Sta.
459582.216	459582.216	459582.216	459582.216	459582.216	459582.2	459582.2	459582.2	459582.2	459554.128	1
459554.128	459554.128	459554.128	459554.128	459554.128	459554.1	459554.1	459554.1	459554.1	459570.095	2
459573.511	459573.511	459573.511	459573.511	459573.511	459573.5	459573.5	459573.5	459573.5	459573.511	3
459572.383	459572.383	459572.383	459572.383	459572.383	459572.4	459572.4	459572.4	459572.4	459572.371	4
459551.618	459551.618	459551.618	459551.618	459551.618	459551.6	459551.6	459551.6	459551.6	459551.607	5
459550.674	459550.674	459550.674	459550.674	459550.674	459550.7	459550.7	459550.7	459550.7	459550.665	6
459533.537	459533.537	459533.537	459533.537	459533.537	459533.5	459533.5	459533.5	459544.9	459530.634	7
459532.011	459532.011	459532.011	459532.011	459532.011	459532.0	459532.0	459532.0	459510.1	459529.730	8

Table 4:Continue

December-E	November-E	October-E	September-E	August-E	July-E	June-E	May-E	April-E	March-E	Sta.
459508.900	459508.900	459508.900	459508.900	459508.900	459508.9	459508.9	459508.9	459490.4	459508.917	9
459486.464	459486.464	459486.464	459486.464	459486.464	459486.5	459486.5	459486.5	459486.5	459487.798	10
459473.830	459473.830	459473.830	459473.830	459473.830	459473.8	459473.8	459473.8	459473.8	459473.830	11
459473.548	459473.548	459473.548	459473.548	459473.548	459473.5	459473.5	459473.5	459473.5	459473.551	12
459534.022	459534.022	459534.022	459534.022	459534.022	459534.0	459534.0	459534.0	459534.0	459534.029	13
459553.480	459553.480	459553.480	459553.480	459553.480	459553.5	459553.5	459553.5	459553.5	459553.468	14
459554.174	459554.174	459554.174	459554.174	459554.174	459554.2	459554.2	459554.2	459554.2	459554.159	15
459574.338	459574.338	459574.338	459574.338	459574.338	459574.3	459574.3	459574.3	459574.3	459574.311	16
459575.084	459575.084	459575.084	459575.084	459575.084	459575.1	459575.1	459575.1	459575.1	459575.066	17
459594.773	459594.773	459594.773	459594.773	459594.773	459594.8	459594.8	459594.8	459594.8	459594.764	18
459587.420	459587.415	459587.415	459587.415	459587.411	459587.4	459587.4	459587.4	459587.4	459587.420	B1
459495.549	459495.549	459495.549	459495.549	459495.549	459495.5	459495.5	459495.5	459495.5	459495.552	B2
459442.427	459442.427	459442.427	459442.427	459442.427	459442.4	459442.4	459442.4	459442.4	459442.429	B3
459542.453	459542.453	459542.453	459542.453	459542.453	459542.5	459542.5	459542.5	459542.5	459542.453	B4
459656.676	459656.671	459656.671	459656.671	459656.676	459656.7	459656.7	459656.7	459656.7	459656.672	B5
459529.562	459529.562	459529.562	459529.562	459529.562	459529.6	459529.6	459529.6	459529.6	459529.569	B6
459417.302	459417.302	459417.302	459417.302	459417.302	459417.3	459417.3	459417.3	459417.3	459417.318	B7

Table 5: Horizontal movement in North direction of point’s observed to the months of March-December 2012

December-E	November-E	October-E	September-E	August-E	July-E	June-E	May-E	April-E	March-E	Sta.
3538614.082	3538614.082	3538614.082	3538614.082	3538614.082	3538614.082	3538614.08	3538614	3538614.1	3538624.59	1
3538624.587	3538624.587	3538624.587	3538624.587	3538624.587	3538624.587	3538624.59	3538625	3538624.6	3538626.53	2
3538617.661	3538617.661	3538617.661	3538617.661	3538617.661	3538617.661	3538617.66	3538618	3538617.7	3538617.66	3
3538596.307	3538596.307	3538596.307	3538596.307	3538596.307	3538596.307	3538596.31	3538596	3538596.3	3538596.30	4
3538573.625	3538573.625	3538573.625	3538573.625	3538573.625	3538573.625	3538573.63	3538574	3538573.6	3538573.61	5
3538572.601	3538572.601	3538572.601	3538572.601	3538572.601	3538572.601	3538572.60	3538573	3538572.6	3538572.58	6
3538548.342	3538548.342	3538548.342	3538548.342	3538548.342	3538548.342	3538548.34	3538548	3538531.4	3538550.70	7
3538544.748	3538544.748	3538544.748	3538544.748	3538544.748	3538544.748	3538544.75	3538545	3538516.6	3538549.71	8
3538526.987	3538526.987	3538526.987	3538526.987	3538526.987	3538526.987	3538526.99	3538527	3538516.4	3538526.98	9
3538523.046	3538523.046	3538523.046	3538523.046	3538523.046	3538523.046	3538523.05	3538523	3538523.0	3538523.98	10
3538527.923	3538527.923	3538527.923	3538527.923	3538527.923	3538527.923	3538527.92	3538528	3538527.9	3538527.91	11
3538542.140	3538542.140	3538542.140	3538542.140	3538542.140	3538542.140	3538542.14	3538542	3538542.1	3538542.14	12
3538506.737	3538506.737	3538506.737	3538506.737	3538506.737	3538506.737	3538506.74	3538507	3538507.3	3538506.74	13
3538528.230	3538528.230	3538528.230	3538528.230	3538528.230	3538528.230	3538528.23	3538528	3538528.2	3538528.23	14
3538528.971	3538528.971	3538528.971	3538528.971	3538528.971	3538528.971	3538528.97	3538529	3538529.0	3538528.98	15
3538551.087	3538551.087	3538551.087	3538551.087	3538551.087	3538551.087	3538551.09	3538551	3538551.1	3538551.09	16
3538551.859	3538551.859	3538551.859	3538551.859	3538551.859	3538551.859	3538551.86	3538552	3538551.9	3538551.90	17
3538573.121	3538573.121	3538573.121	3538573.121	3538573.121	3538573.121	3538573.12	3538570	3538570.3	3538573.11	18
3538611.079	3538611.079	3538611.079	3538611.079	3538611.082	3538611.082	3538611.08	3538611	3538611.1	3538611.07	B1
3538510.707	3538510.707	3538510.707	3538510.707	3538510.707	3538510.707	3538510.71	3538511	3538510.7	3538510.70	B2
3538465.766	3538465.766	3538465.766	3538465.766	3538465.766	3538465.766	3538465.77	3538466	3538465.8	3538465.77	B3
3538446.109	3538446.109	3538446.109	3538446.109	3538446.109	3538446.109	3538446.11	3538446	3538446.1	3538446.11	B4
3538570.960	3538570.960	3538570.960	3538570.960	3538570.960	3538570.960	3538570.96	3538571	3538571.0	3538570.96	B5
3538688.516	3538688.516	3538688.516	3538688.516	3538688.516	3538688.516	3538688.52	3538689	3538688.5	3538688.51	B6
3538564.490	3538564.490	3538564.490	3538564.490	3538564.490	3538564.490	3538564.49	3538564	3538564.5	3538564.49	B7

the same points by 3 mm, the movement are stopped in the following months. For the left side of the barrage, the biggest side in the instability has been observed the following:

Movement points (B1) and 1-3 during the 1st 3 months by 7 mm to the west and towards the river with reduction points by 3-5 mm. In the month of April it was monitored (B1) rise by 4 mm with reduction points 1-3 by 3-5 mm and decline points 10-12 by 3 mm.

In May it has been monitoring the movement (B1) by 5 and 4 mm in the West and the North and monitoring a movement in point (B5) by 3 mm to the North at the same time there is stability in height of (B1) and increase the height of the points (1-3) by 2 mm. In June, it has been monitoring the creep (B1) by 2 mm Westward and 2 mm Northward with the stability in elevations.

Absence of movement during the months of July and August. During September monitoring observed movement (B5) by 5 mm Westward and movement (B1) by 4 mm to the East and 3 mm to the South with the stability of all elevations.

Absence of movement during the months of October and November but during the December monitoring and comparing the results can be summarized movement during the last 3 months crawling in points (B1 and B5) by 5 mm to the East and the descent by 7 mm.

The final result shows that the body of barrage under study fixed and that the movement and crawling limited to payment on both sides, especially, the area around the point (B1), may be the result of exposure to significant load which cause the disintegration of the homogeneity

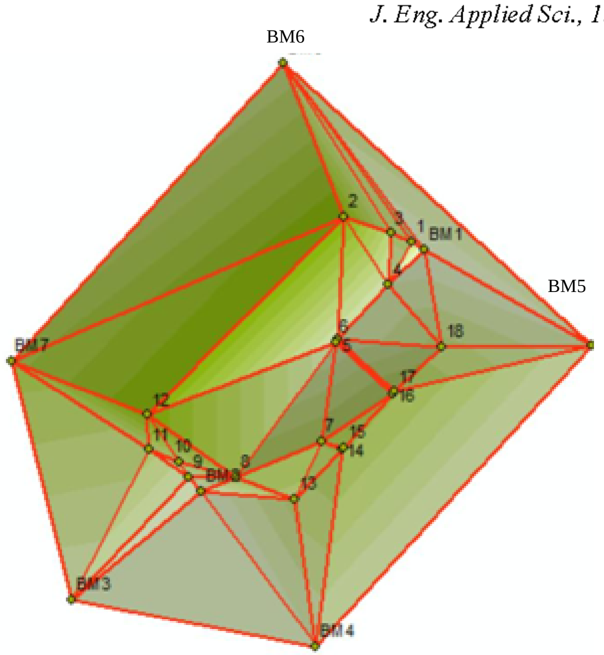


Fig. 7: Micro triangulation control points on and around the barrage

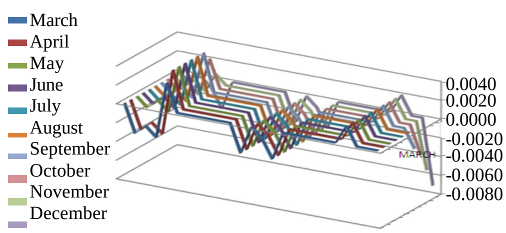


Fig. 8: Vertical movement of point's observed to the months of March-December 2012

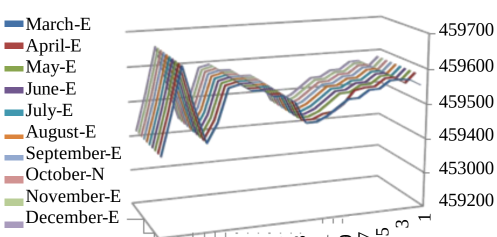


Fig. 9: Horizontal movement in East direction of point's observed to the months of March-December 2012

soils and deep penetration of moisture and helped by the low water levels in the river and the speed of the current as a result of open near the gate all this led to the rush of deep soil in all directions and colliding with the foundations of the wall of Fish escape near the (B1) which leading to cracks and a height in the confluence with the pavement and steadfastness in the points of its confluence with barrage body.

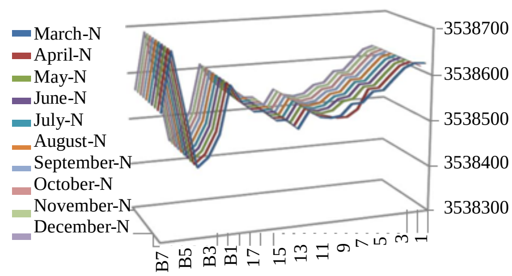


Fig. 10: Horizontal movement in North direction of point's observed to the months of March-December 2012

The process of merge between traditional monitoring devices (total station and level) and GPS provides an accurate and economical control system for barrage.

CONCLUSION

Should be linked monitoring results for the barrage with time (the dimension of time) and non-sustainment study and monitor the movement in dimensions (X-Z) only, It is noted that there are some movements appear at certain periods and opposite movements appear in other periods. Must study the causes of these movements in terms of structure, geotechnical and hydrology.

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