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## Terrestrial Laser Scanning for Dam Deformation monitoring- Case Study

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# FIG WORKING WEEK 2015

## 17-21 MAY SOFIA BULGARIA

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### Agenda

- The EARTHQUAKE in 22 May 2012
- Description of Studena dam
- Geodetic measurements
- Point cloud comparison
- Conclusion

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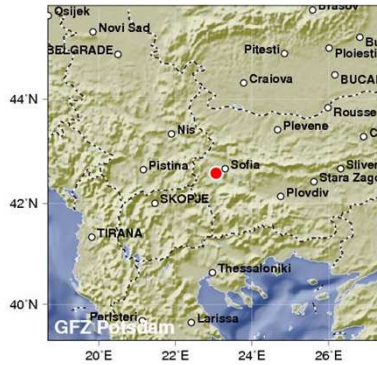
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### The EARTHQUAKE in 22 May 2012



Magnitude: 5.8  
Depth: 10 km  
25 km from Sofia

• Epicenter location in Google Maps

This is a product of the GEOFON Extended Virtual Network (GEVN) and credit belongs to all involved institutions.

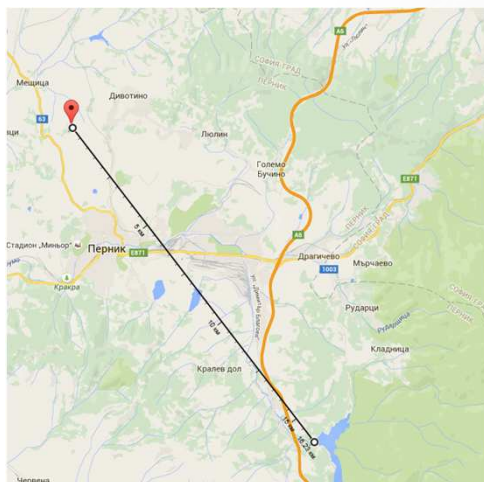


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Studena dam is  
situated 16 km from  
the epicenter of the  
earthquake.



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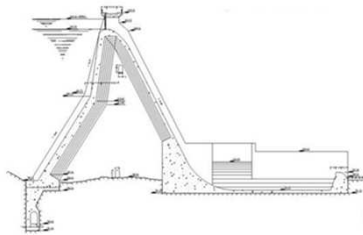


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### Construction of the dam

Studena dam, built in the period 1950-1953 is a *concrete buttress* with 26 concrete blocks- 55 m maximum high and 259 m in length in the crest



Typical cross section of the Studena dam.



Frontal view of the dam



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### Geodetic measurements

1. In December 2011 in the framework of the research project "Use of terrestrial laser scanners for deformation applications"

2. In June 2012 after the earthquake

- Scanner Leica Scan Station C10
- Accuracy 6 mm
- 2 stations 100 m from the dam
- 80 000 000 points
- Scan density 2 cm

	December 2011	June 2012
water level elevation	832.81 m	841.25 m
air temperature	6°C	22°C



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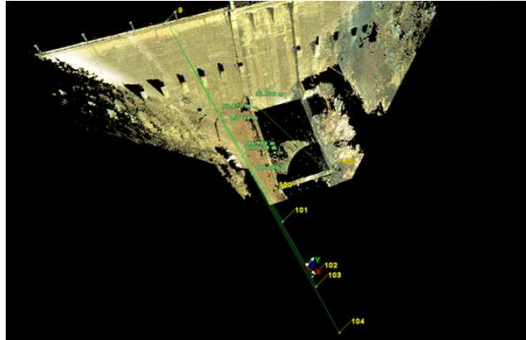




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### Geodetic frame



- 6 new ground control points - 100, 101, 102, 103, 104 and 105
- Total station Leica TCA 1800 with angular accuracy 1 (0.3 mgon) and accuracy of measurement of lengths 1 + 2 ppm.
- Estimated standard deviations of  $\pm 2$  mm in X-Y and  $\pm 3$  mm in Z.



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### Registration of the measurements from both stations

Registration: Registration 2

Constraint ID	ScanWorld	ScanWorld	Type	Status	Weight	Error	Error Vector	
3482	TargetID: 101	Station-002: SW-001 (Leveled)	Station-003: SW-001 (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.003 m	(0.001, -0.001, -0.003) m
3482	TargetID: 102	Station-002: SW-001 (Leveled)	Station-003: SW-001 (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.003 m	(-0.001, 0.000, 0.003) m
3482	TargetID: 103	Station-002: SW-001 (Leveled)	Station-003: SW-001 (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.002 m	(0.000, 0.001, 0.002) m
3482	TargetID: 104	Station-002: SW-001 (Leveled)	Station-003: SW-001 (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.001 m	(0.000, -0.001, 0.001) m
3482	TargetID: 101	Station-002: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.004 m	(-0.002, 0.001, -0.004) m
3482	TargetID: 102	Station-002: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.002 m	(-0.001, -0.002, 0.001) m
3482	TargetID: 103	Station-002: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.002 m	(0.000, -0.001, 0.001) m
3482	TargetID: 104	Station-002: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.004 m	(0.003, 0.001, 0.003) m
3482	TargetID: 103	Station-003: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.002 m	(-0.001, -0.002, -0.001) m
3482	TargetID: 102	Station-003: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.002 m	(0.000, -0.001, -0.002) m
3482	TargetID: 101	Station-003: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.004 m	(-0.003, 0.002, 0.002) m
3482	TargetID: 100	Station-003: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.003 m	(0.001, -0.001, -0.003) m
3482	TargetID: 104	Station-003: SW-001 (Leveled)	coords.TXT (Leveled)	Coincident: Vertex-Vertex	On	1.0000	0.004 m	(0.003, 0.002, 0.002) m

Standard deviation of the registration is **3.1 mm**



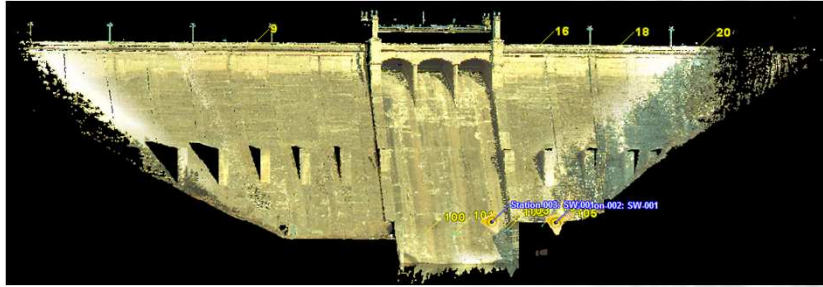




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### 3D model of the dam is obtained with 1 cm density in point cloud



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### Point cloud comparison

- Deformation monitoring using control points
- Direct comparison of single points
- Direct comparison of Digital Elevation Model (DEM)
- Using appropriate approximating surface
- Using plane approximation



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### Surface comparison for deformation extraction

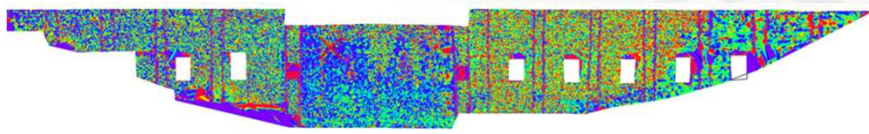
- Direct comparison of Digital Elevation Model (DEM) obtained by two cycles of measurements;
  - AutoDesk Civil 3D
  - PolyWorks - Surface comparison with triangulated models



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### Surface comparison with Civil 3D with triangulated models



**Legend**

-15 to -5 mm	
-5 to +5 mm	
+5 to +15 mm	
+15 to +20 mm	
+20 to +25 mm	

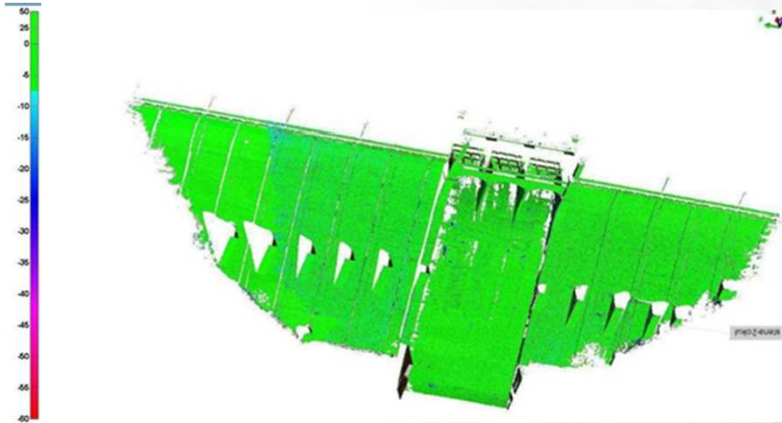




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## Surface comparison with PolyWorks with triangulated models



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## Hidrological conclusion

- The resulting values of the movements correspond to the measurements of the technical operation of the dam.
- Not observed extreme values of the deformation of the surfaces in both measurements.
- Straight verticals in blocks 9 and 16 report and geodetic survey confirmed the elastic nature of these movements, which are in direct relation to the dynamics of water level in the dam and from temperature fluctuations.
- The reported differences are within the limits of the accuracy of the instrument and within the limits of the values measured during the prolonged period of operation of the wall.



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## Future work

- Further investigation on testing different methods and algorithms for deformation extraction is needed



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## Acknowledgement

These research was realized with technical support of **"GEOCAD 93" Ltd.**  
and its specialist in laser scanning eng. Milush Blagoev.



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**Thank you for your attention!**



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