Dynamic Monitoring Of Structures Using A Robotic Total Station

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Introduction

- ✓ It has been demonstrated that robotic total stations (RTS) can be used for dynamic deformation monitoring of structures in certain circumstances with good results (Cosser et al., 2003).
- ✓ The aim of this presentation is to report sets of experiments performed in laboratory, at the University Campus and at Rio Pelotas Bridge using Robotic Total Stations (RTS).
- ✓ LAIG (Geodetic Instrumentation Laboratory) of UFPR has acquired a TCRA 1205 (Leica) in 2002 and already owned a TC 2002 (Leica).

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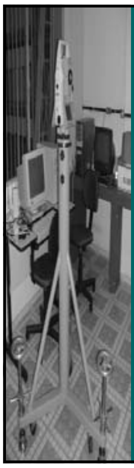

Introduction

Tab. 1 - TCRA 1205 and TC2002 accuracy

	MEASUREMENTS	TCRA 1205	TC 2002
STATIC MODE	DISTANCE	2mm + 2ppm	1mm + 1 ppm
	ANGLE	5"	0,5" ±0,1"
TRACKING MODE	DISTANCE	5mm + 2ppm	----
	ANGLE	5"	-----

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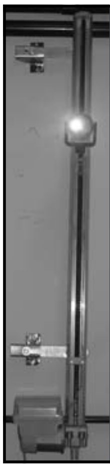

Laboratory Tests

- ✓ 2D oscillator developed in LAIG –UFPR
- ✓ Laboratory testes were carried out to investigate RTS capabilities for continuously monitoring of moving targets and a better understanding about colleted data with different sampling rates.
- ✓ The amplitude was fixed on 0,6 m.
- ✓ The horizontal distance was arranged to 3,45 m due to laboratory space limitations.
- ✓ Two sessions of 240 s of observations at 2 Hz and 0,5 Hz were recorded.
- ✓ TC 2002 was employed to provide lower and upper coordinates.

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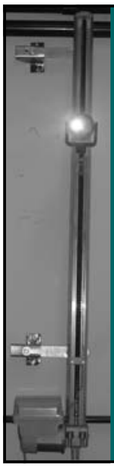
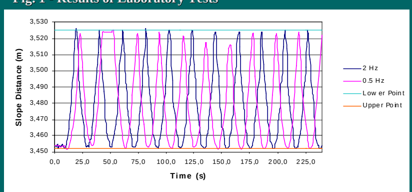


Laboratory Tests

Tab. 2 - Maximum coordinates deviations of laboratoy tests

SAMPLING RATE	MAXIMUM DEVIATION (mm)		
	X	Y	Z
0,5 Hz	1,5	1,5	1,5
2,0 Hz	0,4	0,4	0,4

Fig. 1 - Results of Laboratory Tests



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Tests at the Universty Campus

- ✓ Tests at the University Campus were carried out to investigate the accuracy of TCRA 1205 on dynamic experiments collecting data with different sampling rates, with different prisms and different standoffs for the RTS.
- ✓ Prisms: standard (Leica) and 360º (Leica).
- ✓ Sampling Rate: 1 Hz, 2 Hz and 10 Hz.
- ✓ Distance: 40,574 m, 100,773 m and 146,435 m.
- ✓ Observations recorded in sessions of 150s.

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Tests at the Universty Campus

Tab. 3 - Discrepancies on the results of the tests on the University Campus

Prism	Sampling Rate	TCRA1205 Amplitude	TC2002 Amplitude	Discrepancy between TCRA1205 and TC2002	TCRA1205 Mean Slope Distance	TC2002 Mean Slope Distance	Discrepancy between TCRA1205 and TC2002
	(Hz)	(mm)	(mm)	(mm)	(m)	(m)	(mm)
Standard	1,0	301,7	291,00	10,70	40,575	40,574	1
Standard	2,0	306,0		15,00	40,574		0
Standard	10,0	310,1		19,10	40,574		0
360	1,0	307,1	293,1	14,00	40,574	40,551	23
360	2,0	306,2		13,10	40,574		23
360	10,0	309,7		16,60	40,574		23
Standard	1,0	310,7	294,9	15,80	100,773	100,773	0
Standard	2,0	314,2		19,30	100,773		0
Standard	10,0	305,4		10,50	100,773		0
360	1,0	302,4	294,5	7,90	100,773	100,749	24
360	2,0	331,7		37,20	100,773		24
360	10,0	330,8		36,30	100,773		24
Standard	1,0	304,3	295,7	8,60	146,436	146,435	1
Standard	2,0	324,2		28,50	146,436		1
Standard	10,0	354,7		59,00	146,436		1
360	1,0	340,4	297,2	43,20	146,436	146,411	25
360	2,0	352,5		55,30	146,436		25
360	10,0	351,2		54,00	146,436		25

Tests at the Universty Campus

- ✓ Discrepancies of slope distances smaller than accuracy of the RTS: 1 mm (standard prism); 1,9 mm (360º prism).
- ✓ Prism constant: 23,1 mm.
- ✓ X (4,6 mm), Y (3,4 mm) coordinates smaller than RTS accuracy.
- ✓ Different amplitudes may be explained by:
  - ✓ inicial offset of telescope's crosshairs (± 4mm)
  - ✓ ATR provides a 16" telescope's crosshairs tolerance of the prism center
  - ✓ The curvature of the Earth provides an error of 1,6mm.

Tests at the Universty Campus

- ✓ Total systematic erros: 17,6 mm.
- ✓ Other errors are related to latency.

Tests at the Bridge

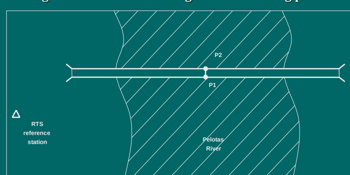
Tests at the Bridge

- ✓ The bridge tests were conducted at Rio Pelotas Bridge which links Rio Grande do Sul State and Santa Catarina State, South of Brazil.
- ✓ The bridge measures 250 m in length, the main span is 189,0 m long and 7,5 m wide.
- ✓ Initial experiments were conducted in order to test the RTS in a high frequency environment.
- ✓ RTS was located on the bedrock, on concrete pillars, about 180 m away from the monitoring points.
- ✓ Two standard prisms (P1 and P2) were mounted on the bridge's handrail.
- ✓ The total station was set up to collect data, of the dynamic traffic load, on two sessions of 85 s, at a rate of 10 Hz.

Tests at the Bridge

- ✓ Two standard prisms (P1 and P2) were mounted on the bridge's handrail.
- ✓ The total station was set up to collect data, of the dynamic traffic load, on two sessions of 85 s, at a rate of 10 Hz, but sampling data rate was not constant during bridge tests and varied around 7 Hz.

Figure 2 - Rio Pelotas Bridge and monitoring points



Tests at the Bridge

Tab. 4 - Standard deviations and displacement amplitudes of bridge test

PRISM	STANDARD DEVIATIONS (mm)			DISPLACEMENT AMPLITUDES (mm)		
	σ_N	σ_E	σ_Z	N	E	Z
P1	0,5	1,0	5,4	13,0	11,0	15,0
P2	2,6	1,2	6,2	3,0	5,0	13,0

- ✓ Different dynamic loads were applied on bridge during session tests.
- ✓ RTS accuracy 5mm + 2ppm.
- ✓ The maximum displacements calculated for reflectors (P1 and P2) are close to that empirically observed (± 14,0 mm).

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Tests at the Bridge

Fig. 3 - Displacementes of reflector 1

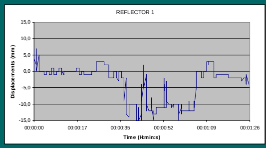
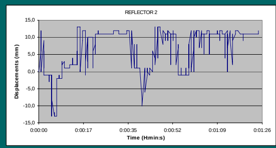


Fig. 4 - Displacementes of reflector 2



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CONCLUSIONS

- ✓ Laboratory ambient (changes in sampling rate): At low speed, RTS measured the movement target well. A higher sampling rate could provide better results, because larger amount of data is recorded.
- ✓ The tests at the University Campus showed that in dynamic monitoring of targets both satandard prism and 360º prism may be used, provinding good precision. In addition, the influence of the growing distance is reflected on the aplitudes of the displacement of the targets.

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CONCLUSIONS

- ✓ The results from the Rio Pelotas Bridge tests showed that monitoring displacements resulted good precisions. The observed displacement amplitudes were close to the empirical amplitude.
- ✓ In all experiments, the RTS precision was above or close to the accuracy provided by Leica. But, the phenomenum of latency produces changes in observations that may be investigated in the future.
- ✓ Other experiments will be conducted by the researches of LAIG in order to identify and mitigate tihs effect.

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Thank You

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