National Technical University of Athens

High Accuracy Deformation Monitoring of a
Concrete Beam using Automatic
Photogrammetric Techniques

Ioanna Chounta & Charalabos Ioannidis

FIG Working Week 2012, 6-10 May 2012, Rome, Italy
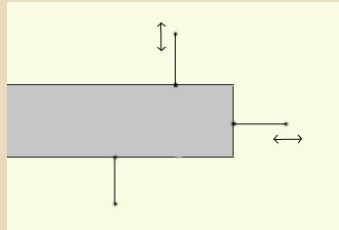
Definition of the problem

The object   Loading procedure   Deformation

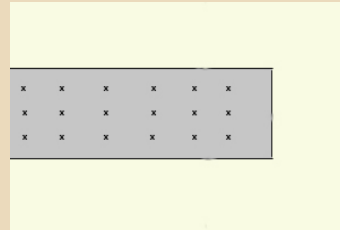## Comparison of approaches for observing the structural behaviour

Contact methods

≠

Non-contact methods

- direct contact with the object
- point – wise
- in one dimension
- high accuracy (10-1000µm)

- from distance
- mass point distribution
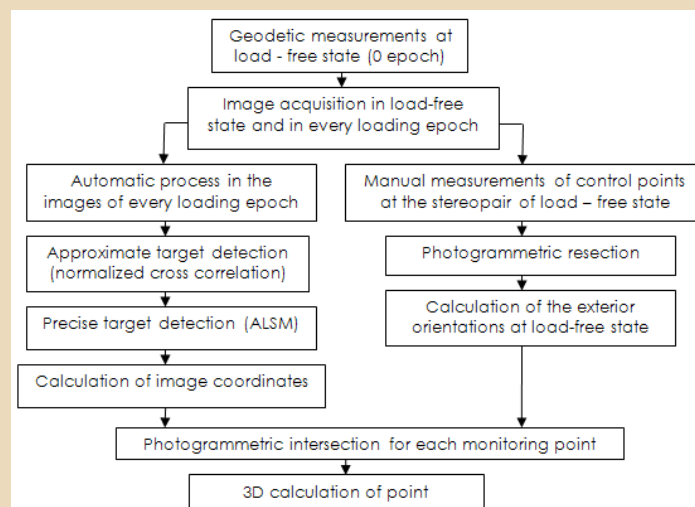- in three dimensions
- comparable accuracy

Prerequisites

- A photogrammetric technique
- 3D monitoring of a great number of points with high accuracy (up to 1mm or better)
- Simplicity of the technique
- On line or almost on line calculation of the results

Proposed procedure (1/4)

- low cost method
- automate image correlation for monitoring of pre-signed points on the surface of a loaded concrete beam in 3 dimensions
- geodetic measurements before the beginning of the loading test
- acquisition of image stereo-pairs during the loading phase
- system of 2 calibrated and synchronized digital cameras
- automated measuring process
- sought accuracy better than 1mm

Proposed procedure (2/4)

Geodetic measurements at load - free state (0 epoch)

Image acquisition in load-free state and in every loading epoch

Automatic process in the images of every loading epoch

Approximate target detection (normalized cross correlation)

Precise target detection (ALSM)

Calculation of image coordinates

Manual measurements of control points at the stereopair of load – free state

Photogrammetric resection

Calculation of the exterior orientations at load-free state

Photogrammetric intersection for each monitoring point

3D calculation of point

Proposed procedure (3/4)

i. **measurements**

- pair of calibrated and synchronized digital cameras
- placement of reflective targets (as control points)
- placement of targets (for automatic image recognition)
- geodetic measurements of the control points

ii. **data acquisition in the test field**

- acquisition of an image stereo-pair at load-free state
- acquisition of the image stereo-pairs at each epoch during the test
- verification stage

Proposed procedure (4/4)

iii. **data processing**

- recording of the synchronised image frames
- image processing (if required)
- calculation of the object coordinates of the control points
- manual measurement of the image coordinates of control points (0-epoch)
- photogrammetric resection (0-epoch)
- automatic localisation and automatic measurements of image coordinates of the monitoring points (every loading epoch)
- photogrammetric intersection
- calculation of the displacements of each point in three dimensions

Automatic detection (1/2)

Stage 1: Approximate detection

Normalized 2D Cross Correlation

- the template lays on every possible position on the image
- the correlation factor is calculated for every position
- the final position of the template is that where the correlation factor has the maximum value

facilitation of the procedure...

- the image is transformed into a binary raster
- a statistical criterion is calculated repetitively until the minimum value is acquired (most appropriate threshold value)
- the tone mean is calculated for every blob and the template
- the normalized correlation factor is recalculated for both the template and the image
- the approximate image coordinates are defined

Automatic detection (2/2)

Stage 2: Precise detection

Adaptive Least Squares Matching

- import of specific parameters
  template size, maximum shift, maximum rotation, maximum number of iterations, color correction (optional), template image, image for the adjustment, center image coordinates on the template, approximate values
- every time the template is detected on the research window, the execution is interrupted
- the image is resampled using bilinear interpolation
- image coordinates are calculated
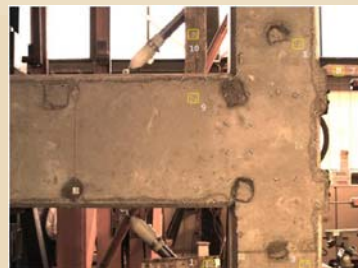
Loading test (1/5)

> Area under study
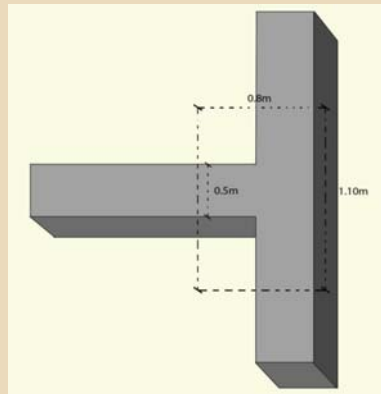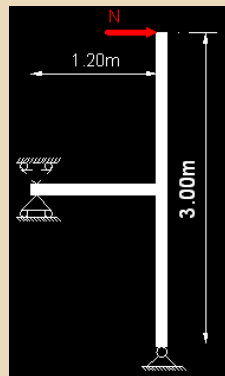
Loading test (2/5)

> Placement of 35 black & white targets
> (+7 more during the test)

> Placement of 11 reflective targets

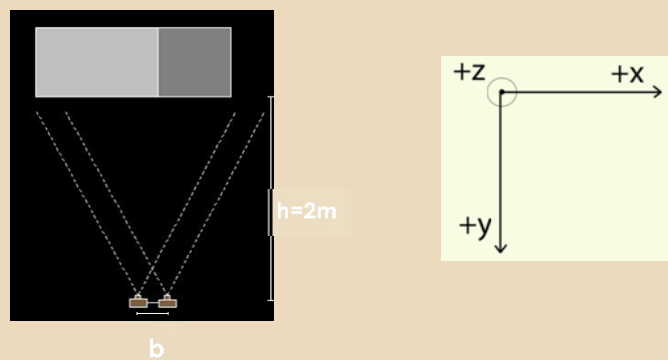## Loading test (3/5)

The configuration of two calibrated and synchronized
Basler A404k/kc digital cameras

Loading test (4/5)

Beam plan

h=2m

b

+z   +x

+y

Loading test (5/5)

➢ Geodetic measurements
(Total Station Leica TDA 5005)

| +18Nt (1st epoch) | -32Nt (2nd epoch) |
| +143Nt (31st epoch) | -157Nt (32nd epoch) |

32 loading epochs
7 hours
to reach ultimate breakage

Data processing & results (1/4)

Photogrammetric Resection

- Load - free state
- 6 control points
- 35 monitored points

	Left image	Right image
Xo	3.5884 m	4.1724 m
Yo	1.9767 m	1.9977 m
Zo	4.7483 m	4.7535 m
ω	0.0627 ^{g}	0.0215 ^{g}
φ	0.0025 ^{g}	0.0163 ^{g}
κ	-0.0049 ^{g}	-0.0050 ^{g}
σ	1.50 pixel	1.59 pixel

Data processing & results (2/4)

Automatic detection

Every time the template is detected on
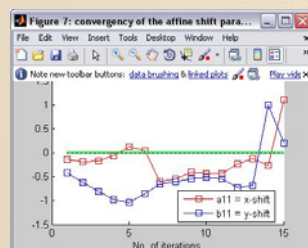the research window...

- the execution is interrupted
- the precise positions of the template are calculated with sub pixel accuracy
- On – screen diagrams
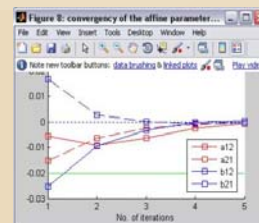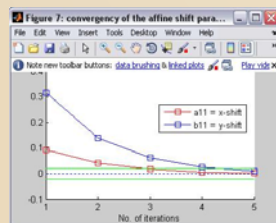
Data processing & results (3/4)

Automatic detection

the phenomenon of impossible
and false correlation appeared in
some cases...
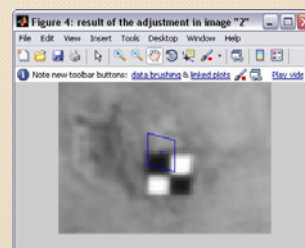
Data processing & results (4/4)

Photogrammetric Intersection

- calculation of the 3D object coordinates of all points to be monitored
- every epoch
- the accuracy of the determined coordinates varies from point to point, (better than 1mm in general)
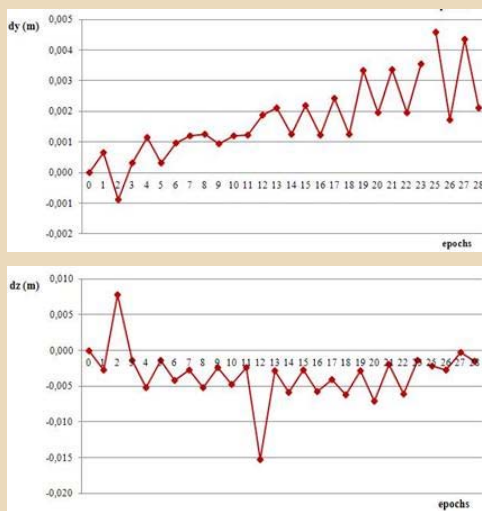
Verification stage & construction of diagrams for
3D displacements of points

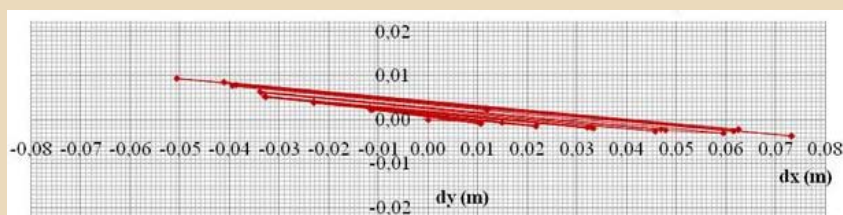## Diagrams of the 3D displacements of points in object space (1/4)

Point 12
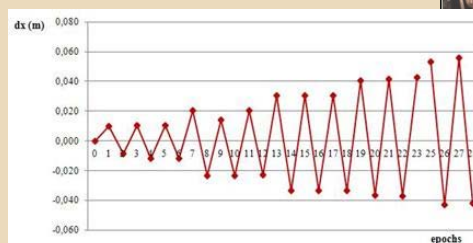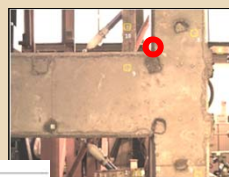
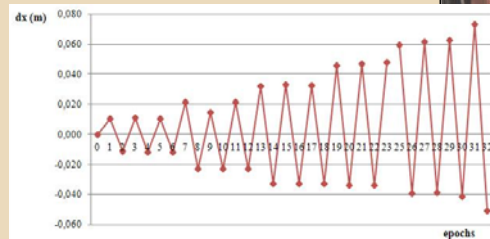## Diagrams of the 3D displacements of points in object space (2/4)
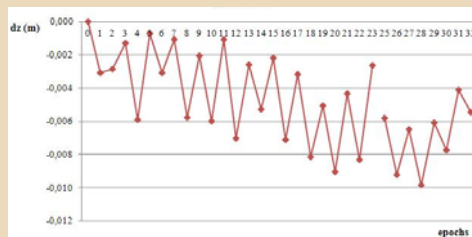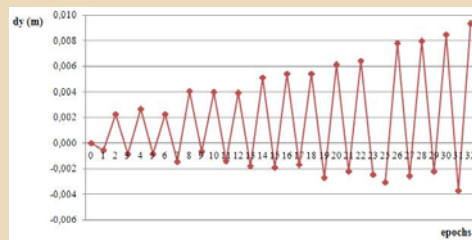

Diagram of the 2D movement of point 12

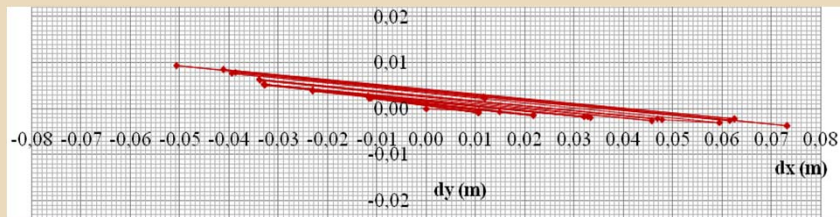# Diagrams of the 3D displacements of points in object space (3/4)

Point 27

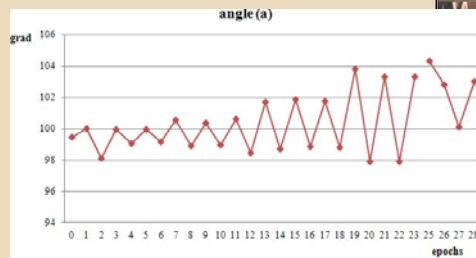

Diagrams of the 3D displacements of points in object space (4/4)

Diagram of the 2D movement of point 27

The size of the upper angle of the beam

Conclusions

✓ simple and low cost technique

✓ calculation of displacements in 3 dimensions

✓ accuracies better than 1mm in the object space

Recommendations…

➤ use of large format synchronized cameras
➤ frames with pre-signed points of known coordinates
➤ use of appropriate coded targets for the points to be monitored
➤ better lighting conditions
➤ use of multi-patch correlation
➤ incorporation of additional geometrical constraints

15

Thank you for your attention...