NOVEL DIGITAL IMAGE CORRELATION INSTRUMENTATION FOR LARGE-SCALE SHAKE TABLE TESTS

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Introduction
Introduction

Objectives

(1) demonstrate the validity of DIC for large-scale and dynamic tests comparable to existing instrumentation techniques;

(2) measure responses that are hard to capture using conventional measurements such as bridge deck planer rotation.
Introduction

Calibration

attach targets
field of view
focusing & exposure

TRITOP
GOM

point in 3D space (X,Y,Z)

epipolar line
epipolar plane
baseline

triangulation
scaling
Introduction

Calibration

on tripod

between cameras
rotate 90deg

move cameras
414-416 = 35.7in
400-408 = 37.5in
Parametric Study
Small Steel Frame

Frame 20inx12inx43in
0.4in (W)
1in (B)

SP 2,3
ACC 1,2,3

Lighting Tripod

Dell Precision #7710
IL5QM4 #16121503; 16121504
Parametric Study
Small Steel Frame

Frame 20inx12inx43in
Top = 44in
Bot. = 45.3in
Frame-cam.center = 14ft
## Parametric Study

**Small Steel Frame**

<table>
<thead>
<tr>
<th>Ground Motions</th>
<th>Earthquake</th>
<th>Max. Disp. (mm/in)</th>
<th>Max. Acc. (g)</th>
<th>Total Duration (sec)</th>
<th>Recorded Duration (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM#1</td>
<td>Sylmar</td>
<td>14/0.55</td>
<td>0.49</td>
<td>20.01</td>
<td>6.535</td>
</tr>
<tr>
<td>GM#2</td>
<td>Rinaldi</td>
<td>66/2.6</td>
<td>0.68</td>
<td>19.91</td>
<td>6.535</td>
</tr>
<tr>
<td>GM#3</td>
<td>Kobe</td>
<td>46/1.8</td>
<td>0.55</td>
<td>40.96</td>
<td>6.535</td>
</tr>
<tr>
<td></td>
<td><strong>Free Vibration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Parametric Study

Small Steel Frame

GM#1-Sylmar

GM#2-Rinaldi

GM#3-Kobe

Time (sec)

\[ \delta_{21} (\text{in}) \]

\[ \delta_{32} (\text{in}) \]
Parametric Study
Small Steel Frame

W/O Add. Mass

1.1lbs

2.2lbs

3.3lbs

4.4lbs

Time (sec)

DAQ

DIC

f = 3.12

T=0.32

f = 3.28

T=0.3

f = 2.6

T=0.38

f = 2.7

T=0.37

f = 3.0

T=0.33
Large Scale App.  
*Shake Table Tests*
# Large Scale App. Shake Table Tests

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Earthquake</th>
<th>Dimension (^{aft;b\text{in}})</th>
<th>Target W/B C/UC</th>
<th>Distance (ft/m)</th>
<th>f/T (Hz/s)</th>
<th>Sampling Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Frame</td>
<td>El-Centro</td>
<td>8.5x8.5x12(^a)</td>
<td>1.5/3 20/6</td>
<td>36/11</td>
<td>1.67/0.6</td>
<td>30</td>
</tr>
<tr>
<td>ABC-2 spans</td>
<td>Northridge</td>
<td>34x11(^a)</td>
<td>1.5/3 17/6</td>
<td>32.8/10</td>
<td>1.72/0.58</td>
<td>30</td>
</tr>
<tr>
<td>CBF</td>
<td>Tohoku</td>
<td>3x3x0.25(^b)</td>
<td>0.7/1.4 16/40</td>
<td>10/3</td>
<td>8.5/0.12</td>
<td>30-100</td>
</tr>
</tbody>
</table>
Large Scale App.
Monitoring Locations
Large Scale App.  
Steel Frame

4th floor-EAST

3rd floor-EAST

2nd floor-EAST

4th floor-WEST

3rd floor-WEST

2nd floor-WEST

<table>
<thead>
<tr>
<th>t</th>
<th>4.66s</th>
<th>6.03s</th>
<th>9.99s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.484</td>
<td>1.484</td>
<td>1.087</td>
<td></td>
</tr>
<tr>
<td>0.993</td>
<td>0.939</td>
<td>0.875</td>
<td></td>
</tr>
<tr>
<td>0.561</td>
<td>0.408</td>
<td>0.599</td>
<td></td>
</tr>
<tr>
<td>-1.273</td>
<td>-1.241</td>
<td>-1.273</td>
<td></td>
</tr>
<tr>
<td>-1.184</td>
<td>-1.093</td>
<td>-1.241</td>
<td></td>
</tr>
<tr>
<td>-0.976</td>
<td>-0.976</td>
<td>-0.976</td>
<td></td>
</tr>
<tr>
<td>1.664</td>
<td>0.939</td>
<td>0.591</td>
<td></td>
</tr>
<tr>
<td>0.939</td>
<td>0.939</td>
<td>0.939</td>
<td></td>
</tr>
<tr>
<td>0.559</td>
<td>0.559</td>
<td>0.559</td>
<td></td>
</tr>
</tbody>
</table>
Large Scale App.  

![CBF Diagram](image)

**RUN#8**
- Time (sec): 0 to 50
- Long. (in): 0 to 2
- Trans. (in): 0 to 2
- Values: -1.17, -1.13, 0.54, -1.37

**RUN#10**
- Time (sec): 0 to 50
- Long. (in): 0 to 2
- Trans. (in): 0 to 5
- Values: -1.93, -1.56, 1.98, -2.2

**RUN#12**
- Time (sec): 0 to 50
- Long. (in): 0 to 2
- Trans. (in): 0 to 5
- Values: -1.65, -1.56, 2.54, -2.78

**RUN#13**
- Time (sec): 0 to 50
- Long. (in): 0 to 2
- Trans. (in): 0 to 5
- Values: -14.83, -14.96, 2.77, -2.08
Large Scale App. 
**ABC-2 SPANS**

\[ \theta = \arctan \left( \frac{\Delta \delta}{128} \right) \]
Large Scale App.  
**ABC-2 SPANS**

<table>
<thead>
<tr>
<th>Earthquake Intensity</th>
<th>$\Delta_{\text{res}}$ (in)</th>
<th>$\theta_{\text{res}}$ (deg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%DE</td>
<td>0.0154</td>
<td>0.0067</td>
</tr>
<tr>
<td>50%DE</td>
<td>0.0482</td>
<td>0.1443</td>
</tr>
<tr>
<td>75%DE</td>
<td>0.0389</td>
<td>0.3756</td>
</tr>
<tr>
<td>100%DE</td>
<td>0.0432</td>
<td>0.4010</td>
</tr>
<tr>
<td>125%DE</td>
<td>0.0694</td>
<td>0.1848</td>
</tr>
<tr>
<td>150%DE</td>
<td>0.0956</td>
<td>0.1898</td>
</tr>
<tr>
<td>175%DE</td>
<td>0.5158</td>
<td>0.6435</td>
</tr>
<tr>
<td>200%DE</td>
<td>0.4683</td>
<td>1.9198</td>
</tr>
</tbody>
</table>

**Orig**

- $20\%\text{DE, max } \phi=0.0316 \degree$
- $50\%\text{DE, max } \phi=0.2021 \degree$
- $75\%\text{DE, max } \phi=0.5652 \degree$
- $100\%\text{DE, max } \phi=0.8460 \degree$
- $125\%\text{DE, max } \phi=0.8850 \degree$
- $150\%\text{DE, max } \phi=1.6318 \degree$
- $175\%\text{DE, max } \phi=1.7310 \degree$
- $200\%\text{DE, max } \phi=2.010 \degree$
# Large Scale App.

**ABC-2 SPANS**

<table>
<thead>
<tr>
<th>Earthquake Intensity</th>
<th>RMSE (in)</th>
<th>DIC $\Delta_{\text{peak}}$ (in)</th>
<th>SP $\Delta_{\text{peak}}$ (in)</th>
<th>NRMSE (%)</th>
<th>$\Delta_{\text{peak}}$ (wrt DIC)</th>
<th>$\Delta_{\text{peak}}$ (wrt SP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%DE</td>
<td>0.0006</td>
<td>0.048</td>
<td>0.038</td>
<td>1.27</td>
<td>1.61</td>
<td></td>
</tr>
<tr>
<td>50%DE</td>
<td>0.0717</td>
<td>0.994</td>
<td>0.992</td>
<td>7.21</td>
<td>7.23</td>
<td></td>
</tr>
<tr>
<td>75%DE</td>
<td>0.1296</td>
<td>1.518</td>
<td>1.145</td>
<td>8.53</td>
<td>11.31</td>
<td></td>
</tr>
<tr>
<td>100%DE</td>
<td>0.1381</td>
<td>1.807</td>
<td>1.574</td>
<td>7.64</td>
<td>8.77</td>
<td></td>
</tr>
<tr>
<td>125%DE</td>
<td>0.1511</td>
<td>2.036</td>
<td>2.403</td>
<td>7.42</td>
<td>6.29</td>
<td></td>
</tr>
<tr>
<td>150%DE</td>
<td>0.1601</td>
<td>3.333</td>
<td>3.349</td>
<td>4.80</td>
<td>4.78</td>
<td></td>
</tr>
<tr>
<td>175%DE</td>
<td>0.2259</td>
<td>3.489</td>
<td>3.897</td>
<td>6.47</td>
<td>5.80</td>
<td></td>
</tr>
<tr>
<td>200%DE</td>
<td>0.3170</td>
<td>3.784</td>
<td>3.947</td>
<td>8.38</td>
<td>8.03</td>
<td></td>
</tr>
</tbody>
</table>
Conclusions

- Identical values for the small-steel frame fundamental frequency were obtained from both sensors;
- Changes in frame frequencies due to the modification of the mass were captured correctly by DIC and DAQ;
- Measurement error (computed from bridge test) was low which gradually increased up to 0.3in as the magnitude of the imposed load was increased;
- The preliminary application of the DIC provides sufficient confidence and promotes DIC capability in the field of instrumentations;
- In summary, the DIC technology demonstrated great potential for dynamic shake table test measurements.