
Appendices

Thesis for the degree of M. Sc. in Geological Engineering

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Delft, The Netherlands
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Appendix 1:

Damage density in % of total number of buildings, Brasilia Nueva area
Damage density in % of total number of buildings per 50x50 m block (source: Castro, 1999). The black square corresponds with the Brasilia Nueva, study area.
Appendix 2:

Fundamental periods for different sites of Armenia obtained from microtremors
Fundamental periods for different sites of Armenia obtained from microtremors
(source: Castro, 1999)

<table>
<thead>
<tr>
<th>CODE</th>
<th>SITE</th>
<th>PERIOD (s)</th>
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<tbody>
<tr>
<td>P001</td>
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<td>CASD</td>
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<td>P003</td>
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<td>GALERIA</td>
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<td>POD8</td>
<td>PARQUE URIBE</td>
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<td>P009</td>
<td>TERMINAL TRANS</td>
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<tr>
<td>P010</td>
<td>VILLA ALEJANDRA</td>
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<td>P011</td>
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<td>VILLA DEL CAFÉ</td>
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<td>ROJAS PINILLA 2</td>
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<td>7 DE AGOSTO</td>
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<td>SENA (SAN JUAN)</td>
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<td>GUAYAQUIL</td>
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<td>P036</td>
<td>CRA. 13 CALLE 7</td>
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<td>P037</td>
<td>CRA 17 CLL 10 (cerca al ISS)</td>
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<tr>
<td>P038</td>
<td>CRA 22 CLL 15</td>
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<td>DIAGONAL COL. INEM</td>
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<td>ESTADIO CENTENARIO</td>
<td>0.33</td>
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</tbody>
</table>
Appendix 3:

Local amplification functions, based on Nakamura Methodology

(a) Measurements from the upper and lower parts of the landslide
(b) Measurements from the lower part covered by the landslide debris, and boundary areas
(c) Measurements along the slope towards the west – Las Delicias
(d) Measurements along the slope towards the east

![Graph of Measurement point NA12](image1)

![Graph of Measurement point NA13](image2)

(e) Measurements in the upper part of the neighbourhood Pinares de Suiza

![Graph of Measurement point NA18](image3)

![Graph of Measurement point NA19](image4)

(f) Measurements of the occidental zone, area above tuffs

![Graph of Measurement point NA16](image5)
(g) Measurements from Santa Tecla

Measurement with 1 Hz seismometer

Measurement with 0.2 Hz seismometer
Appendix 4:

Digital Elevation Models, assessed sections location, hazards maps

4.1 DEM from Armenia, Colombia
4.2 DEM from Armenia, Colombia with damage zonation
4.3 DEM of Brasilia Nueva area
4.4 DEM from the Balsamo Ridge, El Salvador
4.5 Las Colinas landslide location and landslide risk zonation
4.6 DEM of Las Colinas area
Appendix 4.1. DEM from Armenia, Colombia
Appendix 4.3: DEM of Brasilia Nueva area with damages pattern

Legend:
- Apparently no damages
- Cracks & fissures
- Partial collapse
- Total collapse

Scale (m):
0  500
Appendix 4.4: DEM from the El Balsamo Ridge, El Salvador

*Hatched dark orange*: Las Colinas landslide area; *hatched cyan*: paleo-slides; *blue lines with approximate North strike*: assessed sections for the slope stability analysis; *dark orange line*: high risk area; *magenta line*: moderate risk area.
Appendix 4.6: DEM Las Colinas area, with major contour lines and the assessed cross sections in magenta
Appendix 5:

Topographic cross sections from the DEM

5.1 Brasilia Nueva area
5.2 Las Colinas area
5.1 BRASILIA NUEVA AREA

Appendix 5

Topographic cross sections from the DEM
(a) Profile N-S, 469000 S, Las Colinas

(b) Profile E-W, 282325E, Las Colinas area
Appendix 5

(c) Profile N-S, 468750, Las Colinas (Paraiso) area
Appendix 6:

Geometries of the models

6.1 Brasilia Nueva area
6.2 Las Colinas area
GEOMETRIES OF THE MODELS

6.1 BRASILIA NUEVA AREA

(a) North-south cross section

(b) East-West cross section
6.2 LAS COLINAS AREA

(a) North-south cross section, landslide area

(b) West-east cross section

(c) South-north cross section, Paraiso area
Appendix 7:

Script example for the initial static equilibrium stage
Appendix 7

; BRASILIA NUEVA AREA ASSESSMENT E-W
; SECTION 992100 E
; MODEL DIMENSIONS: LENGTH: 988 m, HEIGHT: 160 m
; SLOPE HEIGHT: 42 m
; SLOPE ANGLE: 57 degrees
; ELEMENT SIZE: 4 m
;
new
;
; MODEL DEFINITION
;
config dyn
g 247,40
m m
gen line 0,31 215,40
gen line 215,40 220,33
gen line 220,33 222,30
gen line 222,30 247,30
gen adjust
m n region 2,39
m n region 225,35
gen line 0,24 220,33
gen adjust
m e region 220,20
m e region 2,30
prop d=1560.0 b=5.56e8 s=2.10e8
fix y j=1
fix x i=1 j=1,32
fix x i=248 j=1,31
;
; INITIAL EQUILIBRIUM
;
set grav=9.81
set dyn=off

solve

ini xd=0
ini yd=0
ini xv=0
ini yv=0

m m region 220,20 ; lower layer
prop d=1800.0 b=1.67e9 s=7.70e8 f=36.5 coh=150.0e3 region 220,20
m m region 2,30 ; upper layer
prop d=1560.0 b=5.56e8 s=2.10e8 f=34 coh=74.0e3 region 2,30

solve
;
save consol01 fname Consolidation
return
Appendix 8:

Plasticity state at initial equilibrium stage

8.1 Brasilia Nueva area
8.2 Las Colinas area
PLASTICITY STATE AT INITIAL EQUILIBRIUM STAGE

8.1 BRASILIA NUEVA AREA, COLOMBIA

(a-i) North-south cross section; Mohr-Coulomb constitutive model.

(a-ii) Elastic and Mohr-Coulomb constitutive models.
(b-i) East-west cross section; Mohr-Coulomb constitutive model.

![East-west cross section diagram]

(b-ii) Elastic and Mohr-Coulomb constitutive models.

![Elastic and Mohr-Coulomb models diagram]
8.2 LAS COLINAS AREA, EL SALVADOR

(a-i) North-south cross section; Mohr-Coulomb constitutive model.

(a-ii) Elastic and Mohr-Coulomb constitutive models.
(b-i) South-north – Paraíso cross section. Mohr-Coulomb constitutive model.

(b-ii) Elastic and Mohr-Coulomb constitutive models.
(c-i) West-east cross section; Mohr-Coulomb constitutive model.

(c-ii) Elastic and Mohr-Coulomb constitutive models.
Appendix 9:

**Static equilibrium state: xd, yd, xv, yv**

9.1 Brasilia Nueva area
9.2 Las Colinas area
STATIC EQUILIBRIUM STATE: \( xd, yd, xv, yv \)

9.1 **BRASILIA NUEVA AREA**

(a) North-south cross section: (i) \( x,y \) displacements vs. unbalanced force; (ii) \( x,y \) velocities vs. unbalanced force.
(b) East-west cross section. (i) x,y displacements vs. unbalanced force; (ii) x,y velocities vs. unbalanced force.
9.2 LAS COLINAS AREA

(a) North-south cross section. (i) x,y displacements vs. unbalanced force; (ii) x,y velocities vs. unbalanced force.
(b) South-north – Paraiso cross section. (i) x,y displacements vs. unbalanced force; (ii) x,y velocities vs. unbalanced force.
(c) West-east cross section. (i) x,y displacements vs. unbalanced force; (ii) x,y velocities vs. unbalanced force.
Appendix 10:

Script example for the dynamic loading stage

10.1 FLAC script
10.2 MATLAB filtering script
SCRIPTS FOR THE DYNAMIC LOADING STAGE

10.1 FLAC SCRIPT

; ini xdis=0
ini ydis=0
ini xvel=0
ini yvel=0
;
; DYNAMIC STAGE
;
set dyn=on
set dytime=0

apply ff

set dy_damp=rayl 0.05 3.3

DEF _read_acceleration_file
;
array aa(15000)
IO_READ = 0
IO_WRITE = 1
IO_FISH = 0
IO_ASCII = 1
_filename = 'acc1.txt'
_dummy = open(_filename,IO_READ,IO_ASCII)
_dummy = read(aa,15000)
_dummy = close
;
loop i (1,12600)
xtable(100,i) = parse(aa(i),1)
ytable(100,i) = parse(aa(i),2)
end_loop
;
END
_read_acceleration_file

apply xacc=1.0 his table 100 j=1
apply yvel=0 j=1

his 9 nstep=200
his 10 unbal
his 11 dytime
his 20 xacc i 216 j 41
his 21 xacc i 191 j 40
his 25 xacc i 219 j 37
his 26 xacc i 221 j 34

solve dytime=15 step 1000000

save bnew01_fname_seismic
function highcutfilter(datain,freqlim,filtlen,dataout)

%Function to filter out all frequencies above 'freqlim' which is the cut-off frequency limit.
%All frequencies higher than freqlim are set to zero, while a cosine roll-off taper is used for
%user defined number of points 'filtlen'. filtlen=60 to 100 should be OK to avoid Gibbs phenomena,
%due to too steep filter, in the time domain.
%INPUT
%datain == filename of time sequence to be filtered,
%         a text file is assumed consisting of two columns only,
%         first column is time, with a fixed time step
%         second column is the data to be filtered
%         no other information should be in the file
%example: if filename is earthquake1.txt then datain='earthquake1.txt'
%freqlim == upper frequency limit of high-cut filter
%filtlen == number of points to be used filter for smooth filtering
%dataout == filename for filtered data set in same format as datain

data=load(datain);
dat=data(:,2);
dt=data(2,1)-data(1,1);
ns=length(dat);
df=1./(2*dt*ns);
 nfl=round(freqlim/df)-1;
if nfl >= ns
display 'warning: filter frequency is too high'
end
filt=cos(pi*[0:filtlen]/(2*filtlen)).^2';
dat=[dat,zeros(ns,1)];
dat(ns-filtlen:ns)=dat(ns-filtlen:ns).*filt;
fd=fft(dat);
fú(nfl-filtlen:nfl)=fd(nfl-filtlen:nfl).*filt;
fú(nfl:nfl+1)=zeros(ns+2-filtlen,1);
fú(ns+2:2*ns)=conj(fú(ns:-1:2));
td=real(ifft(fú));
var=[[0:ns-1]'*dt,td(1:ns)];
plot(data(:,1),td(1:ns),'r',data(:,1),data(:,2),'--b')
xlabel('time')
ylabel('amplitude')
title('filtered sequence in red, original in blue')
fid=fopen(dataout,'w');
fprintf(fid,'%7.3f  %16.12f
',var);
fclose(fid);
Appendix 11:

Responses to zero-acceleration histories

11.1 Brasilia Nueva area
11.2 Las Colinas area
RESPONSES TO ZERO-ACCELERATION HISTORIES

11.1 BRASILIA NUEVA AREA

(a-i) North-south cross section, slope ridge

(a-ii) North-south cross section, upper part of the slope, 152 m from the ridge

(a-iii) North-south cross section, slope at the contact between the units
(b-i) East-west cross section, slope ridge

(b-ii) East-west cross section, upper part of the slope at the western boundary of the geometry

(b-iii) East-west cross section, base of the slope
11.2 LAS COLINAS AREA

(a-i) North-south cross section, ridge of the northern slope

(a-ii) Northern slope, contact between upper and middle units

(a-iii) Northern slope, base of the slope
(b-i) West-east cross section, ridge of the slope

![Graph]

(b-ii) West-east cross section, upper part of the slope, 170 m from the ridge

![Graph]

(b-iii) West-east slope, base of the slope

![Graph]
(c-i) South-north cross section, Paraiso area, ridge of the northern slope

![Graph](image1)

(c-ii) South-north cross section, Paraiso area, contact between upper and middle units, northern slope

![Graph](image2)

(c-iii) South-north cross section, Paraiso area, base of the northern slope

![Graph](image3)
Appendix 12:

Results from section E-W,
Brasilia Nueva

12.1 Frequency dependent
12.2 Frequency independent
12.3 Frequency independent, horizontal acceleration
RESULTS FROM SECTION E-W, BRASILIA NUEVA

12.1 FREQUENCY DEPENDENT

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<th>2 Hz</th>
<th>5 Hz</th>
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</table>

**Plasticity state:**

- Elastic
- Elastic, Yield in Past

**Shear strain & Displacement vectors:**

- Max shear strain increment
  - Contour intervals: 5.00E-04
  - Max Vector: 1.372E-02

- Displacement vectors
  - Max Vector: 6.902E-01

**x-displacements:**

- Contour interval: 2.50E-03

**x-velocities:**

- Contour interval: 6.00E-10
y-displacements:

y-velocities:

Stress state:

Maximum stress:

Minimum stress:
### 12.2 Frequency Independent

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<th>E-W acceleration history</th>
<th>Vertical acceleration history</th>
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<td><strong>Plasticity state:</strong></td>
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<td><img src="image1" alt="E-W acceleration history" /></td>
<td><img src="image2" alt="Vertical acceleration history" /></td>
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<tr>
<td><strong>Shear strain &amp; Displacement vectors:</strong></td>
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<td><strong>y-displacements:</strong></td>
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<td><img src="image9" alt="y-displacements" /></td>
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</tbody>
</table>
y-velocities:

Stress state:

Maximum stress:

Minimum stress:
12.3 FREQUENCY INDEPENDENT, ONE-LAYER MODEL

E-W acceleration history

Plasticity state:

Shear strain & Displacement vectors:

x-displacements:

x-velocities:
y-displacements:

y-velocities:

Stress-state:

Maximum stress:

Minimum stress:
12.4 Frequency Independent, Horizontal Acceleration

**E-W acceleration history**

Plasticity state:

Shear strain & Displacement vectors:

x-displacements:

x-velocities:

y-displacements:
y-velocities:

Stress state:

Maximum stress:

Minimum stress:
Appendix 13:

Results from section N-S,
Brasilia Nueva

13.1 Frequency dependent and frequency independent
RESULTS FROM SECTION N-S, BRASILIA NUEVA

13.1 FREQUENCY DEPENDENT AND FREQUENCY INDEPENDENT

2 Hz

Plasticity state:

Shear strain & Displacement vectors:

x-displacements:
x-velocities:

y-displacements:

y-velocities:
Stress state:

Maximum stress:

Minimum stress:
Appendix 14:

Results from section N-S,
Las Colinas

14.1 Frequency dependent and frequency independent
RESULTS FROM SECTION N-S, LAS COLINAS

14.1 FREQUENCY DEPENDENT AND FREQUENCY INDEPENDENT

2.86 Hz

Plasticity state:

Shear strain & Displacement vectors:

x-displacements:

x-velocities:
y-displacements:

y-velocities:

Stress state:

Maximum stress:

Minimum stress:
Appendix 15:

Results from section N-S,
Las Colinas (Paraiso)

15.1 Frequency dependent and frequency independent
RESULTS FROM SECTION N-S (PARAISO), LAS COLINAS

15.1 FREQUENCY DEPENDENT AND FREQUENCY INDEPENDENT

2.86 Hz

Plasticity state:

Shear strain & Displacement vectors:

x-displacements:
x-velocities:

y-displacements:

y-velocities:
Stress state:

Maximum stress:

Minimum stress:
Appendix 16:

Results from section E-W, Las Colinas

16.1 Frequency independent
RESULTS FROM SECTION E-W, LAS COLINAS

16.1 FREQUENCY INDEPENDENT

**E-W acceleration history**

Plasticity state:

Shear strain & Displacement vectors:

x-displacements:
Appendix 16

x-velocities:

y-displacements:

y-velocities:

Stress-state:
Maximum stress:

Minimum stress: