EARTHQUAKE ENGINEERING RESEARCH CENTRE
UNIVERSITY OF ICELAND

ISSEE2009
International Symposium on Strong-motion Earthquake Effects

University of Iceland
Háskólatorg - Campus Centre
Auditorium HT103/HT101
Reykjavik

9:00 – 16:00, 29 May 2009


University of Iceland Campus Centre

UNIVERSITY OF ICELAND
SCHOOL OF ENGINEERING AND NATURAL SCIENCES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

Programme of the Symposium

9:00-9:15	**Opening Address by Dr. Kristín Vala Ragnarsdóttir, Dean of School of Engineering and Natural Sciences, University of Iceland**
9:20-10:20	**Session 1 - Chairman : Ragnar Sigbjörnsson** (Auditorium HT103)
9:20-9:40	ICEARRAY and the M_w6.3 Ölfus earthquake on 29 May 2008 in South Iceland: Extreme near-fault strong-motion array recordings B. Halldórsson, R. Sigbjörnsson
9:40-10:00	Examples and Characteristics of Fault Interaction in the South Iceland Seismic Zone K. S. Vogfjörd, S. Hjaltadóttir, H. Geirsson and R. Slunga
10:00-10:20	The 29 May 2008 Ölfus Earthquake: The Icelandic Strong-motion Network recordings and attenuation S. Ólafsson, R. Sigbjörnsson and J. Th. Snæbjörnsson
10:20-10:40	*Coffee Break*
10:40-12:00	**Session 2 - Chairman : Símon Ólafsson** (Auditorium HT103)
10:40-11:00	The 29 May Ölfus Earthquake: Structural response and observed damage. J. Th. Snæbjörnsson
11:00-11:20	Ground-Motion Prediction Equations for inelastic response R. Rupakhety and R. Sigbjörnsson
11:20-11:40	Psychological effects of the 29 May Ölfus Earthquake in Iceland: Preliminary findings B. Guðmundsdóttir and M. Blöndal
11:40-12:00	Recovery guidelines for local government and community staff S. Thorvaldsdóttir, Á.E. Bernharðsdóttir, H. Sigurjónsdóttir, G. Oddsson and G. Pétursdóttir
12:00-1:00	*Lunch Break*
1:00-2:20	**Session 3 - Chairman : Benedikt Halldórsson** (Auditorium HT101)
1:00-1:20	Near fault ground motions: Outstanding problems A. S. Papageorgiou
1:20-1:40	Response of inelastic Steel Moment Resisting Frames (SMRFs) to near-fault ground motion. R. Rupakhety and A. S. Papageorgiou
1:40-2:00	Recovering ground displacement and velocity time series using wavelet decomposition A. A. Chanerley, N. Alexander and B. Halldórsson
2:00-2:20	The Hellenic Accelerographic Network: Enhancements towards automated real-time data acquisition I. S. Kalogeras, D. Loukatos, N. S. Melis and K. Boukouras
2:20-2:40	*Coffee Break*
2:40-4:00	**Session 4 - Chairman: Jónas Thór Snæbjörnsson** (Auditorium HT101)
2:40-3:00	Analysis of the 29th May 2008 Ölfus earthquake and aftershock sequence using three-component array processing on ICEARRAY S. J. Gibbons and B. Halldórsson
3:00-3:20	Determination of Source Parameters of Local Earthquakes Using Moment Tensor Inversion of Single Station Data. D. Malytskyy
3:20-3:40	Seismic early warning applied to the Kross Earthquake of May 29th 2008. E. Kjartansson, H. Sveinbjörnsson, B. Thorbjarnardóttir, S. Hjaltadóttir, G. G. Pétursson and K. S. Vogfjörð.
3:40-4:00	Real-time mapping of strong-motion effects and damage estimates using ICEARRAY technology B. Halldórsson, H. Avery, J. Berrill, and R. Sigbjörnsson

ICEARRAY AND THE M_W6.3 ÖLFUS EARTHQUAKE ON 29 MAY 2008 IN SOUTH ICELAND: EXTREME NEAR-FAULT STRONG-MOTION ARRAY RECORDINGS

Benedikt Halldórsson[1], Andrew A. Chanerley[2], Nicholas Alexander[3], Ragnar Sigbjörnsson[1]

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Abstract

The Mw6.3 Ölfus earthquake on May 29th 2008 in Iceland occurred in the western part of the South Iceland Seismic Zone (SISZ). The earthquake rupture was complex, rupturing two parallel, vertical right-lateral strike slip faults 4-5 km apart, with a time lag of ~2 seconds. While the earthquake produced intense near-fault strong- motion and caused significant and widespread damage in the area, it resulted in no loss of lives and in general did not compromise the structural integrity of a vast majority of the buildings. The town of Hveragerdi suffered the heaviest damage being in the extreme near-fault region of the earthquake (rupture distance ~1-2 km). The strong-motion in the town was recorded on the ICEARRAY, the first small-aperture strong-motion array in Iceland. These unique recordings all exhibit intense high- frequency motion with horizontal PGA of 0.44-0.87g and prominent near-fault velocity pulses along both the strike-normal and strike-parallel horizontal directions. The linear response spectra indicate that the long-period energy of the velocity pulse seen along the strike-normal direction is not present in the strike-parallel direction. Furthermore, the period of the pulse is shorter along the strike-parallel and more distinct in the frequency domain, than that of the pulse seen on the strike-normal component. The amplitudes are however greater along the latter direction which moreover exhibits a more repetitive (cyclic) behaviour, possibly reflecting the complex source effects. The Eurocode 8 "Type 2" design spectrum combined with a design spectrum for near-fault motion with distinct pulses appears to capture well the overall spectral composition of the ICEARRAY response spectra. Moreover, the acceleration time histories have been corrected based on a novel wavelet transformation approach and integrated to reveal the true velocity and displacement. Both the strike-normal and strike- parallel components are associated with permanent tectonic displacement that does not take place simultaneously. The results of this study emphasize the need for specific code provisions for near-fault sites taking into account near- fault velocity pulses and permanent displacements.

References

Halldorsson, B., R. Sigbjornsson and J. Schweitzer (2009). ICEARRAY: the first small-aperture, strong-motion array in Iceland. *Journal of Seismology*, vol. 13, no. 1, p. 173–178. Doi: 10.1007/s10950-008-9133-z.

Sigbjörnsson, R., J.Th. Snæbjörnsson, S.M. Higgins, B. Halldórsson, S. Ólafsson (2009). A note on the M6.3 earthquake in Iceland on 29 May 2008 at 15:45 UTC. *Bulletin of Earthquake Engineering*, vol. 7, no. 1, p. 113-126, DOI: 10.1007/s10518-008-9087-0.

Halldorsson, B. and R. Sigbjornsson (2009). The Mw6.3 Ölfus Earthquake at 15:45 UTC on May 29 2008 in South Iceland: ICEARRAY strong-motion recordings. *Soil Dynamics and Earthquake Engineering*, vol. 29, p. 1073-1083, DOI:10.1016/j.soildyn.2008.12.006.

Chanerley AA, Alexander NA, "Correcting Data from an Unknown Accelerometer using Recursive Least squares and Wavelet De-noising", *J. Computers and Structures*, 85, 1679- 1692, 2007

EXAMPLES AND CHARACTERISTICS OF FAULT INTERACTION IN THE SOUTH ICELAND SEISMIC ZONE

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Abstract

The eastward shift of the rift zone in southern Iceland, along the South Iceland Seismic Zone builds up stress in this transform zone, which is released every century in a sequence of significant earthquakes. The earthquakes, which occur on parallel faults perpendicular to the shear zone, usually start in the eastern part and sequentially move westward over the length of the zone in a period of days to years. There are also instances of dynamic triggering, where the waves from one earthquake have triggered other significant earthquakes, tens of kilometers away. Such dynamic triggering occurred twice in the ongoing sequence, in 2000 and again in the most recent earthquake in May 2008.

The 2008 earthquake was caused by slip on two parallel faults. It was felt over most of SW Iceland and strongly felt in near-by towns, Hveragerði and Selfoss. The seismic stations closest to the faults were saturated, but 3 cm/s peak ground velocity was recorded on the national seismic network, SIL at 46 km distance. The event was captured on the continuous GPS network, with maximum horizontal displacement of 19 cm measured 2.5 km SE off the Ingólfsfjall fault. Details of the fault structures are mapped through relative location of aftershocks, showing two parallel 8-km-wide, vertical faults and an adjacent E-W oriented fault, which was last active at the end of the Hengill seismic swarm in 1998. Seismic data from the first few seconds following the first arriving P-wave are analyzed in order to determine the onset of slip on the second fault. An overview of fault interaction and fault patterns of previous earthquakes in the ongoing sequence is also presented.

THE 29 MAY 2008 ÖLFUS EARTHQUAKE: THE ICELANDIC STRONG-MOTION NETWORK RECORDINGS AND ATTENUATION

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Abstract

The Icelandic Strong-Motion Network (IceSMN) was established in 1984 and provides coverage of the most active seismic zones in South and North Iceland. The IceSMN is operated by the Earthquake Engineering Research Centre of the University of Iceland (www.afl.hi.is). The objective of the Network is to collect data required for structural design and risk management and provide measurements of ground motion and structural response in earthquakes. Strong- motion records from the largest earthquakes acquired by the Network are included in the ISESD databank (Internet Site for European Strong Motion Data, www.isesd.hi.is).

Attenuation formulas play a central role in seismic hazard assessment but often give widely different results depending on earthquake regions and research groups producing them. A model based on a point source approximation, using few physically intuitive parameters, has been developed with the main purpose of estimating ground motion for engineering purposes. The model has been applied to Icelandic earthquakes and parameters have been estimated from the acceleration records by means of inversion. The application of this model to the peak ground acceleration in the 29 May 2008 Ölfus earthquake is presented for modelling attenuation. A comparison with shallow strike-slip earthquakes from other regions of the world is presented and attenuation formulas based on data from North America and Europe.

THE 29 MAY ÖLFUS EARTHQUAKE: STRUCTURAL RESPONSE AND OBSERVED DAMAGE

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Abstract

This study will focus on the South Iceland earthquakes in 2000 and 2008. This study examines the data recorded and the damage observed immediately after the event. In these events horizontal accelerations of up to 80% g were recorded in the epicentral regions and there is visual evidence that the vertical acceleration exceeded 1 g. In general the basic properties of the South Iceland earthquakes in 2000 and 2008 are found to show similar characteristics. The peak acceleration is high but duration of motion is short and attenuates rapidly with increasing distance. The earthquake action resisted by buildings in the near fault area is inspected through evaluation of response spectra and study of response data available from several structures in South-Iceland and Reykjavik. This data is used to examine system parameters, such as natural frequency and structural behaviour. In addition an example is given from a study of a reinforced cast-in-place concrete building where earthquake induced acceleration data has been systematically collected over period of 19 years. The system identification based on the sampled data serves both as a baseline for damage identification as well as calibration for further structural modelling of the buildings. Visible damage in the buildings studies is slight, but the system parameters, at least in some cases, reflect structural changes.

Although considerable property damage occurred in the South Iceland earthquakes in 2000 and 2008, the vast majority of structures seemed to withstand the strong-motion fairly competently and without significant visual damage. This is due firstly to the low-rise, predominantly reinforced concrete or timber, style of buildings. Secondly, the short duration of strong-motion contributed to the endurance of structures.

GROUND MOTION PREDICTION EQUATIONS FOR INELASTIC RESPONSE

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Abstract

The mainstream approach of estimating design forces for seismic-resistant design is based on a linear elastic response spectrum, commonly constructed by scaling a predefined spectral shape with the peak ground acceleration corresponding to the hazard at a given site. Inelasticity in structures is taken into consideration by using so-called structural behaviour factors or force reduction factors. While a predefined spectral shape can not capture the true nature of ground motion, the reduction factors defined in seismic design codes are too simplified. We propose empirical equations to compute the peak response of 5% damped elastic-perfectly-plastic single-degree-of-freedom systems having a predefined ductility demand. In addition, seismic evaluation and design verification requires simplified procedure to compute the ductility demand of systems whose strength is either established by the designer or can be estimated. We propose another set of empirical equations to serve this purpose. Proposed equations relate structural response t o the earthquake magnitude, source-to-site distance, and the ground type and are calibrated by using 182 ground acceleration records obtained Iceland, continental Europe and the Middle East. These equations can easily be incorporated into probabilistic frameworks to perform probabilistic seismic hazard assessment or probabilistic seismic demand assessment.

References

Rupakhety, R., R. Sigbjörnsson (2009). Ground-motion prediction equations (GMPEs) for inelastic response and structural behaviour factors. *Bulletin of Earthquake Engineering*, DOI 10.1007/s10518-009-9105-x

Rupakhety, R., R. Sigbjörnsson (2009). Ground-motion prediction equations (GMPEs) for inelastic displacement and ductility demands of constant-strength SDOF systems. *Bulletin of Earthquake Engineering*, DOI 10.1007/s10518-009-9111-6

PSYCHOLOGICAL EFFECTS OF THE 29 MAY 2008 ÖLFUS EARTHQUAKE IN ICELAND: PRELIMINARY FINDINGS

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Abstract

In the last few decades, earthquakes have been among the largest natural disasters in the world (WHO, 1980). The negative psychological and economic effects of earthquakes can be immense and last for many years (e.g., Basoglu, et al., 2002; Salcioglu, et al., 2007).

Historically, earthquakes have been a destructive natural force in Iceland, the most earthquake prone area in Northern Europe. Despite strong earthquakes in Iceland in the last decade, very little scientific attention has been given to their psychological effects. Thus, the purpose of the current report was to examine the psychological impact of the May 29 2008 earthquake in South Iceland, which caused widespread and significant damage. The current report had two goals, first to examine how individuals in the affected area perceived the earthquake, and second to examine the early signs of PTSD symptoms and depression two to three months following the earthquake. Participants were 1514 individuals (aged 18 to 80 years) who were randomly selected from the National Registry of Iceland and lived in the affected area during the earthquake. After agreeing to participate, individuals received questionnaires which included questions about the perception of the earthquake, if they received assistance following the earthquake and prior history of traumatic experience. Additionally, participants were asked to complete the PTSD Symptom Scale-Self Report, (PSS-SR; Foa, et al., 1993) and the Beck Depression Inventory-II (BDI-II; Beck, et al., 1996).

Preliminary results showed that 78% of participants reported significant fear, helplessness or horror during the earthquake, thus meeting criteria A for PTSD according to the DSM-IV. Additionally, 7.1% of participants reported significant post trauma symptoms (as measured by PSS-SR) and 7.1% reported moderate to severe depressive symptoms (as measured by BDI-II) 2-3 months following the earthquake. Women were significantly more likely to meet criterion A for PTSD and report both post trauma and depressive symptoms. This study provides critical information on the psychological effects of earthquakes in Iceland. To date this area has significantly been lacking scientific attention. Furthermore, the current study may offer knowledge on health care needs of individuals following earthquakes. Benefits and limitations of this methodology will be discussed.

References

Basoglu, et al., 2002;
Beck, et al., 1996
Foa, et al., 1993
Salcioglu, et al., 2007

Collaborators

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RECOVERY GUIDELINES FOR LOCAL GOVERNMENT AND COMMUNITY STAFF

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Abstract

In 2006 to 2008 the University of Iceland and Rainrace Consulting Service headed a research and development project focusing on immediate and long-term recovery aspects at the community level, due to natural disasters. The project involved experts in the field of crisis management, community employees with experience from previous events, members of the affected population, response personnel and members of national and local government institutions. The community of Isafjardarbaer participated as a key partner, due to their relevant experience in recent years, to give insight into community aspects relating to disasters. The project was funded by The Icelandic Centre for Research (RANNIS), The Icelandic Catastrophe Fund (Viðlagatrygging Íslands), The Ministry of Justice and the Ministry of Social Affairs (Bjargráðasjóður). The results were a set of guidelines for key staff and local government, and an outline of a temporary and evolving management system for the recovery process, that incorporates members of society.

The project began with an analysis in order to identify key assumptions and factors, forming 11 principles to guide the development process. The process methodology was developed throughout the project and is one of the project outputs. The methodology is based on two anchor-points: first, a detailed understanding of the impact on society, the consequences and the needs of the affected population, and second, the daily routines of those using the guidelines. The daily routines are then adapted to problems facing local government and staff, based on practices used in emergency response and in international relief and recovery operations.

Draft versions were being edited the moment the May 29th earthquake struck and were shortly after adopted by the Arborg and Hveragerdi communities by general resolution, after being adapted for local conditions. The mayor of Arborg stated that the guidelines were extremely useful, but stressed that such guidelines are more useful if they are adapted to local conditions and staff trained before the disaster strikes. The critical question then becomes how to gain the interest of communities before a disaster strikes.

NEAR-FAULT GROUND MOTION: OUTSTANDING PROBLEMS

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Abstract

Near-fault ground motions exhibit certain characteristics which can be anticipated and described using simple (deterministic) mathematical models. Specifically, when the rupture is 'sub-shear', the fault-normal component of velocity exhibits a strong pulse of intermediate frequency that carries a lot of destructive potential. A simple mathematical model has been recently proposed by Mavroeidis and Papageorgiou to describe such pulses. The key parameters of the model are the amplitude of the pulse A and the duration of the pulse T_P. By fitting the model to the then existing database of near-fault motions, it was observed that A is a fairly stable parameter, while T_P grows with earthquake size. It was also observed that T_P is controlled by (and thus strongly correlated to) the 'rise-time' τ, and consequently it is correlated to the characteristic sub-event size of the main event (i.e. to the 'barrier interval' $2\rho_0$, in the terminology of the 'Specific Barrier Model'). The model has been successfully used by various investigators in modelling near-fault strong ground motion.

In view of the above, and given that the *rise- time τ* of *intra-plate* events is shorter as compared to the same parameter of *inter-plate* events, Halldorsson et al. (2003) proposed that T_P of intra-plate events is shorter as compared to T_P of inter-plate events. The then existing database was supportive of the above hypothesis but was very limited. Therefore, a clear task is to augment the database of intra-plate events and test the validity of the above hypothesis.

When the rupture is *super-shear*, it has been observed that the fault-parallel component of motion is at least as large as the fault-normal one. It necessary to identify more narrowly the waveform characteristics of the near-fault pulses generated by super-shear ruptures, and to recognize the segments of faults that potentially could generate super-shear rupture.

References

Mavroeidis, G. P. & Papageorgiou, A. S. (2003). A Mathematical Representation of Near-Fault Ground Motions *Bull. Seism. Soc. Am.*, 93, 1099-1131

Mavroeidis, G. P.; Dong, G. & Papageorgiou, A. S. (2004). Near-Fault Ground Motions, and the Response of Elastic and Inelastic Single Degree-of-Freedom (SDOF) Systems *Eq. Eng. Str. Dyn.*, 33, 1023-1049

Halldórsson, B.; Ólafsson, S. & Sigbjörnsson, R. (2007). A Fast and Efficient Simulation of the Far-Field and Near-Fault Earthquake Ground Motions Associated with the June 17 and 21, 2000, Earthquakes in South Iceland *J. Eq. Eng.*, 11, 343- 370

Halldorsson, B.; Mavroeidis, G. & Papageorgiou, A. S. (2009). Near-Fault and Far- Field Strong Ground Motion Simulation for Earthquake Engineering Applications Using the Specific Barrier Model *Journal of Structural Engineering,* (accepted, in- press)

Halldorsson, B.; Mavroeidis, G. P. & Papageorgiou, A. S. (2003). Estimation of Near-Fault Velocity Pulses for Intra-Plate Earthquake Sources, Proceedings of the Annual Meeting of the Eastern Section of the Seismological Society of America, Toronto, Canada.

RESPONSE OF INELASTIC STEEL MOMENT RESISTING FRAMES (SMRFs) TO NEAR-FAULT GROUND MOTIONS

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Abstract

Engineering structures in the vicinity of causative earthquake faults have experienced severe damage during strong earthquakes of the past decade. Forward directivity and fling effects have been identified by the seismologists as the primary characteristics of near-fault ground motions. It has been observed that the near-fault ground motions with forward rupture directivity are characterized by a large pulse, which is mostly oriented perpendicular to the fault. Because of the unique characteristics of the near-fault ground motions and their potential to cause severe damage to structures designed to comply with the criteria mostly based on far-field earthquakes, it is necessary to characterize and parameterize these special types of ground motions by simple and reliable mathematical models having input parameters which have clear physical meaning and scale to the earthquake magnitude. One of the most successful models available in the literature is the one proposed by Mavroeidis and Papageorgiou (Mavroeidis & Papageorgiou, 2003). The main objective of this study is to investigate if such simplified models, which have been proved to be effective and accurate for SDOF systems, are capable of predicting the response of MDOF systems. Generic frame models with 6 different heights and three levels of design ductility have been used to evaluate their response to 20 actual near-fault ground motions and the corresponding pulses calibrated to them. It has been found that the equivalent mathematical model being evaluated in this work is capable of estimating, fairly accurately, the base shear demand, the maximum inter-story drift and the height-wise distribution of inter-story drifts for the regular plane moment resisting frames used in this work.

References

Mavroeidis, G. P. & Papageorgiou, A. S. (2003). A Mathematical Representation of Near-Fault Ground Motions *Bull. Seism. Soc. Am.*, 93, 1099-1131

Mavroeidis, G. P.; Dong, G. & Papageorgiou, A. S. (2004). Near-Fault Ground Motions, and the Response of Elastic and Inelastic Single Degree-of-Freedom (SDOF) Systems *Eq. Eng. Str. Dyn.*, 33, 1023-1049

Displacement and Fling using the Wavelet Transform with ICEARRAY Data

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Abstract

The research in this presentation applies the stationary-wavelet transform at a suitable level of decomposition to extract the long-period; type A sine, fling model from ICEARRAY recorded acceleration time histories. The long period, acceleration fling should be as close to the theoretical type A model as possible, leading to a pulse-type velocity and ramp-like displacement after 1st and 2nd integration. The wavelet transform decomposes the seismic record using maximally flat filters and these together with a de-noising scheme from the core of this approach to extract the long sub-band acceleration, velocity and displacement profiles and to automatically correct for baseline shift. The long period fling is relatively easily obtainable at the right level of decomposition, from which the long period velocity and displacement follow. The ICEARRAY recorded 33 acceleration time histories from 11 base stations using the CUSP 3Clp seismograph, when the 29th May 2008, 6.3 magnitude seismic event occurred. Each has been processed using the wavelet transform methodology and produced resultant displacements close to the 17cm NW verified by GPS. The methodology was also applied to the 1999 Chi-Chi earthquake, which was a 7.3 magnitude event. In both cases the low- frequency fling was extracted and velocity and displacement time histories obtained.

References

Chanerley AA, Alexander NA, "Correcting Data from an Unknown Accelerometer using Recursive Least squares and Wavelet De-noising", *J. Computers and Structures*, 85, 1679- 1692, 2007

Sigbjörnsson, R., J.Th. Snæbjörnsson, S.M. Higgins, B. Halldórsson, S. Ólafsson (2009). A note on the M6.3 earthquake in Iceland on 29 May 2008 at 15:45 UTC. *Bulletin of Earthquake Engineering*, vol. 7, no. 1, p. 113-126, DOI: 10.1007/s10518-008-9087-0.

Halldorsson, B. and R. Sigbjornsson (2009). The Mw6.3 Ölfus Earthquake at 15:45 UTC on May 29 2008 in South Iceland: ICEARRAY strong-motion recordings. *Soil Dynamics and Earthquake Engineering*, vol. 29, p. 1073-1083, DOI:10.1016/j.soildyn.2008.12.006.

Chanerley, AA., Alexander, NA., Obtaining estimates of the low-frequency 'fling', instrument tilts and displacement timeseries using wavelet decomposition, submitted to *Bulletin of Earthquake Engineering*, December 2008

THE HELLENIC ACCELEROGRAPHIC NETWORK: ENHANCEMENTS TOWARDS AUTOMATED REAL-TIME DATA ACQUISITION

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Abstract

The Institute of Geodynamics, National Observatory of Athens (NOA-IG) is operating a strong ground motion network in Greece since the end of the 60s, although the first processed and archived record can be found during 1973. An upgrade of the network with the installation of the first 14 digital instruments started during 1995 and continues until today. Currently, the network consists of 79 stations that cover the whole region of Greece. 74 of the deployed instruments are digital (Geotech Instr. A800 and A900, Kinemetrics QDR and ETNA, Guralp CMG-5TD), and 5 analogue (Kinemetrics SMA-1), the latter still in good operational condition. Local accelerographic arrays have also been deployed in urban areas and operate today (i.e. Athens, Rethymno and Heraklio).

Since the majority of the accelerographic stations are hosted in Public Service Buildings (i.e. Municipalities, Prefectures, Regional Offices, Hospitals, Schools, Telecommunication Buildings etc), an effort was made to link all of them, via available internet link, to the NOA-IG base in Athens and establish a system, with the appropriate software, to monitor state of health, synchronize in accurate GMT time the instruments without available GPS on site and finally download accelerometric data after a recorded earthquake.

The great challenge of this effort was to provide the necessary hardware and software, in order to enhance "traditional" accelerographic instruments, equipped with serial interfaces and exhibiting diverse operational characteristics, with modern network functionality. This requires not only several upgrades in terms of physical interconnections, but also design and implementation of the necessary intermediate software modules.

At a following stage, routing and firewall issues were solved appropriately in order for a Central Controller Entity (CCE), hosted in a Linux computer at NOA-IG premises, to communicate fluently with each remote instrument, one-by-one. The role of the CCE includes several modules concerning different purposes:

Software driver modules are used for the CCE to directly communicate with each remote serial device via the established IP connection and to download the serial information via TCP/IP sockets.

A main daemon is responsible to pass any necessary command to the accelerograph of interest or to listen to any activity or response from the remote instrument. Thus, the daemon acquires the operating status of the instrument, downloads any new event recorded and stores the information into appropriate log files.

A separate module synchronizes the clocks of all the instruments using an accurate time reference from a GPS-equipped accelerograph, since the instrument maintenance in real-time conditions and

the processing of the records are crucial for the network operational reliability.

All the gathered information (operational status and records) is available for web access and/or further arithmetic post processing via modules that are implemented separately on a second Linux computer, which is hosted at the NOA-IG premises.

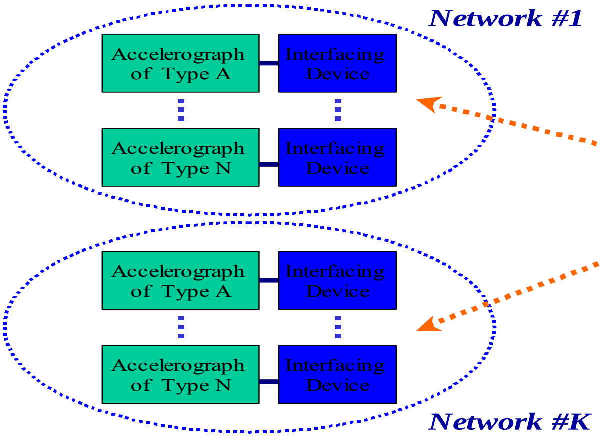

Figure 1 A schematic diagram of the developed

The project is partially supported by the Information Society S.A. and partially by the General Secretariat of Research and Technology.

ANALYSIS OF THE 29TH MAY 2008 ÖLFUS EARTHQUAKE AND AFTERSHOCK SEQUENCE USING THREE- COMPONENT ARRAY PROCESSING ON ICEARRAY

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Abstract

The ICEARRAY small aperture strong motion seismic array in Hveragerdi, Iceland, produced high quality recordings of the Mw 6.3 29 May 2008 Ölfus earthquake and its extensive aftershock sequence. The geometry of the array was chosen to provide accurate and stable direction estimates for seismic phases in the frequency range 1-10 Hz, and a preliminary data analysis has provided a good overview of the seismicity distribution in the month following the main event. The short source-to-receiver distances place additional constraints upon the processing parameters (e.g. data window length) which can be used in obtaining slowness estimates.

However, standard broadband f-k analysis in windows of duration of the order 1 second provides stable direction estimates for the initial P-phases from most aftershocks using only the vertical component traces of the array.

Arrival-time and slowness estimation for secondary phases, necessary for event location accuracy, is complicated by the dominance of the P-coda on the vertical seismograms. However, S- phases are remarkably coherent between sensors on the rotated horizontal components allowing improved onset time measurement and robust slowness estimates.

Correlation analysis of the aftershock sequence indicates many clusters of events with very similar waveforms, and often with clear S-P travel time differences. We anticipate highly improved accuracy in relative event location estimates by using array phase estimates together with cross- correlation differential travel-time measurements.

The difference in frequency content between the main event and the far small aftershocks makes a direct comparison between slowness estimates from broadband f- k analysis difficult. Performing Principal Component Analysis (PCA) on covariance matrices calculated using multitaper coherence measurements on short time-windows allows for a very stable f-k analysis in narrow frequency bands. The PCA allows for a far better separation of the coherent arriving wavefronts and the incoherent ground motions, and allows the evolution of the incoming wavefronts with time to be compared for the main event and numerous aftershocks close to the location of first rupture.

DETERMINATION OF SOURCE PARAMETERS OF LOCAL EARTHQUAKES USING MOMENT TENSOR INVERSION OF SINGLE STATION DATA

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Abstract

Moment tensor inversion techniques using body wave synthetic seismograms have been developed. The synthetics are calculated using the matrix method. We offer a method to get displacements on the free surface of layered structure for first P and S waves. These synthetic seismograms are windowed from the onset of P and S to arrivals of multiply reflected P and S. Results of a direct problem are used for estimating temporal variation of seismic time function (STF). We show that components of seismic moment tensor as functions of time can be restored by inversion to their original shape and values, as used in a direct problem. We test the inversion in case when velocity model is known exactly. These methods were good tool for an estimation of earthquake source process and time in a source with the help of STF.

The procedure of the moment tensor inversion was applied to Mw=3.6 earthquake of 16 October 1998, $15^h27^m53.9^s$, 44.00°N, 33.67°E (epicenter distance – 66 km). The problem of determining STF using a single station data is resolvable and may be applied to improve our knowledge of physical processes in the source.

SEISMIC EARLY WARNING APPLIED TO THE KROSS EARTHQUAKE OF MAY 29 2008

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Abstract

Tools for real-time analysis have been implemented at seismic stations in the SIL system in Iceland, as a part of the Icelandic Meteorological Office participation in the SAFER and TRANSFER projects. These tools include processes to support alert maps and Shake Maps, and the development of procedures to map faults in near-real-time.

Data for alert maps and Shake Maps is obtained using a real-time process that monitors both ground velocity and acceleration in 4 separate frequency bands at each station: 4-50 Hz, 1-10 Hz, 0.25-2.5 Hz and 0.05-0.5 Hz. A reference level is maintained for horizontal and vertical components in each frequency band, such that it is exceeded a few times per hour. When signals exceed this level by more than 50%, a report is sent to the processing center. When 5 or more stations send reports within a time interval of 20 seconds, alert maps are generated. The alert maps show observed values for each station. An attempt is also made to solve for the location of the event. All possible combinations of 3 stations are used to compute potential solutions; the location that yields the lowest sum of absolute residuals for all stations is then selected.

Once the location has been determined, conventional magnitude can be calculated, using attenuation relations describing the decay of ground velocity with distance. This relationship is extracted from velocity records of the SIL network. The attenuation relation for acceleration, derived from the velocity records, agrees well with the relation obtained from the Icelandic Strong motion network (Ólafsson and Sigurjónsson).

When a good fit is obtained for at least 5 stations, for both arrival times and amplitudes, and the magnitude indicated is greater than 2.0, a ShakeMap is generated and placed online automatically. The Shake Maps are usually ready within 3-4 minutes of the earthquake. The maps can be accessed at http://hraun.vedur.is/ja/alert. Once information on the fault is available, this information can be incorporated into the ShakeMap generation. ShakeMaps for the Kross earthquake show good agreement with intensity observations.

REAL-TIME MAPPING OF STRONG-MOTION EFFECTS AND DAMAGE ESTIMATES USING ICEARRAY TECHNOLOGY

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Abstract

Traditional arrays using a central recording facility and dedicated communications channels to continuously record data are expensive to deploy and maintain. A lower cost alternative is to install a network of stand-alone instruments, each operating in a “triggered recording” mode with local storage and near-real-time generic communications. Natural and cultural conditions generally result in varying background noise levels across the sites of a given network and therefore, event detection and recording should be optimized to produce complete data sets, even for frequent small and local earthquakes, without creating masses of spurious records at individual nodes. This is especially the case for networks of small aperture. This is achieved by employing a tuned “common-triggering” (CT) scheme in which selected instruments are configured to send trigger notification messages over the Internet to one or more central hubs, each running the CT detection algorithm. Whenever a preset number of alerts are received within a moving time window, a global trigger command is issued to all instruments within the network, effectively ensuring complete network coverage. This scheme was implemented for the ICEARRAY, the first strong-motion array in Iceland, consisting of 14 CUSP-3Clp broadband, tri-axial, strong-motion accelerographs equipped with GPS based timing and perpetual GPRS Internet communications over an aperture of 1.9 km. We show that the CT scheme maximizes the array's efficiency in recording real events and at the same time minimizes the analyst's efforts in reviewing data. This scheme markedly improves the usefulness of a network of stand- alone instruments by converting it into an array with little or no additional cost and allows sites with marginal triggering suitability to be effectively incorporated as slave instruments.

Additionally, the triggering alert package from each instrument contains real- time information on two fundamental characteristics of strong-motion parameters: the peak- ground acceleration (PGA) and duration of motion (T). Historically, the PGA is the most commonly used ground motion parameter since it is used to determine the lateral inertial forces in structures and is the reference parameter for earthquake resistant design. T plays a direct role in the destructiveness of an earthquake and is furthermore modulated by directivity effects. Together the PGA and T measurements at each site provide an estimate of the probability of earthquake damage to a given structural type. This is especially important in the near-fault region as source complexities such as sub-event location on the fault plane and direction and speed of rupture generally generate a non-symmetrical distribution of near-fault strong motion. Using this ICEARRAY technology the engineers can provide real-time estimates of the damage potential in the near-fault region. Providing the authorities responsible for disaster management and rescue efforts immediately after an earthquake with such information has the potential of focussing the rescue and response efforts without delay after a destructive earthquake.

References

Halldorsson, B. and H. Avery (2009). Converting strong-motion networks to arrays via common- triggering, *Seismological Research Letters* (accepted, in press).

Halldorsson, B., R. Sigbjornsson and J. Schweitzer (2009). ICEARRAY: the first small-aperture, strong- motion array in Iceland. *Journal of Seismology*, vol. 13, no. 1, p. 173–178. Doi: 10.1007/s10950-008-9133-z.