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EReS EARTHQUAKE RESILIENT SCHOOLS

European Commission

Deliverable Title: Publications and Presentations

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WP 5: Communication & Dissemination

Publications and Presentations

DELIVERABLE COORDINATED BY:
ORGANISMOS ANTISEISMIKOU SXEDIASMOU KAI PROSTASIAS (OASP EPPO EARTHQUAKE PLANNING AND PROTECTION ORGANIZATION) (ITSAK/EPPO)

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DIETHNES PANEPISTIMIO ELLADOS (IHU)

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PROJECT DETAILS

	EUROPEAN COMMISSION Directorate-General for European Civil Protection and Humanitarian Aid Operations (ECHO) ECHO.B – Disaster Preparedness and Prevention B.2 – Prevention and Disaster Risk Management
Project No	101101206
Project Name	Earthquake Resilient Schools
Project Acronym	EReS
Call	UCPM-2022-PP
Topic	UCPM-2022-PP
Type of action	UCPM Project Grants
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Lead Partner	DIETHNES PANEPISTIMIO ELLADOS (IHU)
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Project Coordinator	Papatheodorou K. (IHU)

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1 BACKGROUND OF THE DOCUMENT

1.1 RELATED WORKPACKAGE AND TASKS

This document describes the activities that took place in the framework of the WP5 and is related to Task 5.4: Publications and Presentations (of project research outputs).

1.2 SCOPE AND OBJECTIVES

This document presents the Publications and Presentations accomplished within the EReS project. Early Scientific work during and in the framework of the project has been mainly presented and published in National and International Conferences. In addition, more mature scientific work is going to appear soon (as delay is expected due to peer review process) in international peer-reviewed Journals, promoting accordingly results of the EReS project.

2 PUBLICATIONS AND PRESENTATIONS

2.1 Introduction

In the framework of the EReS project, original scientific work has been initiated with respect to seismic hazard and risk assessment in the Greek-Turkish Cross-Border Area, to site effects in the accelerometers stations involved in the project as well as in the training and education framework with respect to the output of the EReS. In the following section, the titles of several publications/presentations are given. In the ANNEX all corresponding Abstracts arealso provided.

2.2 Titles of the pubications /presentations in the framework of the EreS

The following papers have been presented or/and are accepted for presentation in:

(A) The European Geophysical Union Conference, hold in Vienna, Austria, 28-30 April, 2025.

1. Kourou, A., Theodoulidis, N., Konstantinidou, K., Papanikolaou, V., Papatheodorou, C., Kirtas, E., Panagopoulos, G., Nurlu, M., Sezer, S., Kuterdem, K., Zulfikar, C., Mert Tugsal, Ü., and Ergen, V. (2025). Earthquake Resilient Schools in High Seismicity Areas of Europe: The case of Greece-Türkiye Cross Border Area, EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025, EGU25 - 15086, https://doi.org/10.5194/egusphere-egu25-15086, 2025.

2. Chatzianagnostou, E. and Theodoulidis, N. (2025). 1D Site characterization of National Accelerometer stations in Greece based on earthquake recordings and the Diffuse Filed Concept (DFCe), EGU General Assembly 2025, Vienna, Austria, 27th April to 2nd May 2025, EGU25 - 8382, https://doi.org/10.5194/egusphere-egu25-8382, 2025.

3. Theodoulidis N., Hollender F., Rischette P., Buscetti M., Doustebacque I., Grendas I. and Roumelioti Z. (2025). Characterization of selected "rock" reference stations of the Hellenic Accelerometer Network (HAN).

(B) The Hellenic Conference of Earthquake Engineering and Engineering Seismology (ETAM) to be hold in Athens, 30 Oct. – 1 Nov. 2025

1. Chatzianagnostou E., Theodoulidis N. (2025). Site characterization of Accelerometer stations in Greece based on earthquake recordings and the Diffuse Field Concept (DFCe).
2. Θεοδουλίδης Ν., Γρένδας Ι. (2025) Εκτίμηση ισχυρής εδαφικής κίνησης μεγάλων σεισμών στον Ελληνικό χώρο: Η περίπτωση του καταστρεπτικού σεισμού (Μ7.2) της Κεφαλονιάς 1953 (in Greek)
3. Θεοδουλίδης Ν., Παπανικολάου Β., Ιωάννης Γρένδας Ι., Κωνσταντινίδου Κ., Καρακώστας Χ. (2025). Δίκτυο Επιταχυνσιογράφων εντός Πολεοδομικού Συγκροτήματος και Συμβολή στη Μείωση της Σεισμικής Διακινδύνευσης. (in Greek)
4. Χατζηαναγνώστου Ε., Θεοδουλίδης Ν., Γρένδας Ι., Shible H., Hollender F. (2025). Αξιολόγηση της κατηγοριοποίησης των εδαφικών συνθηκών και των παραγόντων ενίσχυσης του Ευρωκώδικα 8. (in Greek).

(C) The Turkish National Conferences in February and April 2025, Ankara.

1. Nurlu, M., Türkoğlu, M., Kuterdem, K., Aksel, D., Köksal, T.S. ve Tekin, B.M., 2025, Okullarda Yerbilimlerine Olan İlgiyi Artırmak İçin Örnek Bir Uygulama "Okul Sismolojisi", Uluslararası Katılımlı 77. Türkiye Jeoloji Kurultayı, 14 - 18 Nisan 2025, Ankara (in Turkish).
2. Nurlu, M., Kuterdem, K., Sezer, S., Köksal, T.S., Türkoğlu, M., Tekin, B., Özsaraç, V., Şentürk, M.D., Aksel, D., Kılıç, N., Zülfikar, C. Ve Tuğsal, Ü.M., 2025, Okulları Depreme Dirençli Hale Nasıl Getiririz?, Türkiye'nin Afet Risk Yönetimi Yirmiyedinci Yuvarlak Masa Toplantısı, ODTU, 23 Şubat 2025, Ankara (in Turkish).

(D) In International Journals

1. Chatzianagnostou E., N. Theodoulidis, I. Grendas, E. Ito, H. Kawase (2025), Estimation of Vertical Amplification Correction Function (VACF) in Greece based

on the Generalized Inversion Technique of Strong Motion and Diffuse Field Concept on Earthquakes, Bull. Seism. Soc. Am., (accepted for publication).

ANNEX A

Abstracts and Manuscripts of EReS project related Publications

A.1

EGU General Assembly 2025

Earthquake Resilient Schools in High Seismicity Areas of Europe: The case of Greece-Türkiye Cross Border Area

Asimina Kourou[1], Nikolaos Theodoulidis[2], Kiriaki Konstantinidou[2], Vassileios Papanikolaou[3], Constantine Papatheodorou[4], Emmanouil Kirtas[4], George Panagopoulos[4], Murat Nurlu[5], Selim Sezer[5], Kerem Kuterdem[5], Can Zulfikar[6], Ülgen Mert Tugsal[7], and Volkan Ergen[7]

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In high seismicity regions, one of the greatest risks to population safety is the catastrophic impact of earthquakes. Among the critical societal infrastructures at risk are school buildings, which house both students and staff. In earthquake-prone countries, enhancing the preparedness of schools to address seismic risks is essential. This effort raises two fundamental questions for authorities: (a) what are the most effective measures to create earthquake-resilient schools? (b) How can civil protection agencies contribute to achieving this goal?

To address question (a), building earthquake-resilient schools requires a multifaceted approach combining structural, educational, and policy-driven measures. Key actions include implementing structural and engineering reinforcements, developing robust policies and securing funding, providing education and training programs, fostering community involvement, utilizing technology for real-time monitoring and ensuring effective post-disaster recovery plans. For question (b), civil protection agencies play a pivotal role in supporting earthquake-resilient schools by leveraging their expertise, resources, and coordination capabilities to enhance prevention, preparedness, response, and recovery efforts.

A joint effort, within the framework of the European project Earthquake Resilient Schools (EReS), has been initiated to promote earthquake resilience in the Cross-Border Area (CBA) of Greece and Türkiye. The project focuses on harmonizing seismic hazard and risk assessments in the CBA and implementing joint preventive and response measures against potential earthquake disasters. Four pilot sites—two in Greece (Alexandroupolis and Samos) and two in Türkiye (Izmir and Canakkale)—have been selected for monitoring specific school buildings, using low cost-New Gen instrumentation (accelerometers). School Seismology practices have been applied in Çanakkale and Alexandroupolis to contribute to awareness raising of school community as a pilot study. Real-time seismic data from these schools are streamed to the Computer Centers of respective institutions for analysis, for predicting rapid prediction of structural damage, such as inter-story drift and stiffness degradation. These findings are expected to enhance seismic preparedness and to provide tools for rapid post-earthquake assessments.

In parallel, educational and training activities were conducted for students and staff, along with preparedness drills at the pilot sites. The benefits of this collaborative effort in the CBA are discussed, highlighting its contribution to enhancing earthquake resilience in schools. Finally, recommendations for further steps to strengthen school preparedness and safety against seismic risks are proposed.

A.2

EGU General Assembly 2025

1D Site characterization of National Accelerometer stations in Greece based on earthquake recordings and the Diffuse Filed Concept (DFCe)

Eirini Chatzianagnostou and Nikolaos Theodoulidis
Institute of Engineering Seismology and Earthquake Engineering, Engineering Seismology & Earthquake Engineering, Greece (echatzian@gmail.com)

This study presents the site characterization of 133 selected stations in the National Accelerometer Network of Greece. All available earthquake recordings for various distances, magnitudes and azimuths around the station are compiled and processed to estimate a stable and reliable average Horizontal -to-Vertical Spectral Ratio (eHVSR). The earthquake records used have magnitude range $4 \leq M < 6$, with focal depth ranging from 0 to 40km and hypocentral distances 12 km $\leq R_{hyp} \leq$ 300 km. Using the Diffuse Filed Concept for earthquakes (DFCe), and incorporating limited a priori geological information, available for the area around the station, the estimated eHVSRs were utilized in an inversion framework to estimate the best misfit velocity profiles down to seismological bedrock (where Vs>=3km/sec). Comparisons of these estimated velocity profiles with existing ones for the selected stations based on other geophysical or/and geotechnical methods, revealed good agreement, encouraging broader application of this methodology for the rest of stations.
In accordance with recommendations from the SERA project, seven key indicators were calculated for each of the 133 stations and are presented as follows: (1) Resonance frequency (f_0), (2) Shear wave velocity of the uppermost 30 meters (Vs_{30}), (3) Surface geology description, (4) Current EC8 site class, (5) Depth of the seismological bedrock ($H_{3km/s}$), (6) Depth of the engineering bedrock ($H_{0.8km/s}$) and (7) Vs_Z full profiles where available. Such comprehensive site characterization of accelerometer stations enhances regional and international strong-motion databases (e.g. ESM db) and contributes to exploiting earthquake recordings to their full potential for engineering and seismological applications.

A.3

EGU General Assembly 2025

Characterization of selected “rock” reference stations of the Hellenic Accelerometer Network (HAN)

Nikos Theodoulidis[1], Fabrice Hollender[2], Pauline Rischette[2], Margaux Buscetti[2], Isabelle Doustebacque[3], Ioannis Grendas[1], and Zafeiria Roumelioti[4]
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In Greece, almost all accelerometer stations provided accelerometer recordings, more than 400 in total, are characterized by inferred Vs30 values based on combination of surface geology and slope proxy (Stewart et al. 2014). However, only about 15% of them have been characterized by insitu geophysical and geotechnical methods (invasive or/and non-invasive) were performed at a distance less than 100m from the station. In addition, regarding reference rock stations where shear wave velocity Vs30 is equal or greater than 800m/sec (engineering bedrock), only five (5) of them have been characterized todate, with respective values ranging between 800Vs301183m/s. It is evident that measured site characterization parameters of accelerometer stations in Greece is far from a desired goal, especially regarding those on rock reference sites. In this study multiple/combined non-invasive passive and active seismic techniques are applied in six (6) accelerometer stations throughout Greece, to improve earthquake site characterization metadat of the national accelerometer network, focusing on stations placed on geologic rock conditions. The Vsz (S-wave) and Vpz (P-wave) profiles and thereby Vs30 site class according to the Eurocode-8 are determined. In addition, to form a holistic picture of the site’s characterization, surface geology and topographic properties are provided for the investigated stations. Results of this study aim at contributing on improving site characterization parameters estimated by the Generalized Inversion Technique (source, path, site), as well as in defining Ground Motion Models for rock site conditions.

B.1

ΠΣΑΜΤΣ
ΑΘΗΝΑ 30, 31 ΟΚΤ, 1 ΝΟΕ 2025

Site characterization of Accelerometer stations in Greece based on earthquakerecordings and the Diffuse Field Concept (DFCe)

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ΠΕΡΙΛΗΨΗ
The scope of the present study is to address recommendations of the SERA EU project for site characterization, by providing seven key indicators for stations of the National Accelerometric Network in Greece. These indicators include (1) fundamental resonance frequency (f_0), (2) shear wave velocity in the uppermost 30 meters (V_{S30}), (3) surface geology description, (4) Eurocode 8 site classification, (5) subsurface shear-wave velocity structures, (6) depth to engineering bedrock ($H_{0.8km/s}$), and (7) depth to seismological bedrock (H3km/s). To achieve this goal, all available earthquake recordings, triggered by shallow crustal earthquakes with magnitudes ranging from four to six and event-to-station hypocentral
distances up to 300 km were compiled, for 133 stations. Then the Horizontal-to-Vertical Spectral Ratios of earthquakes (eHVSRs) for each event and station were calculated. Implementing the Diffuse Field Concept for earthquakes (DFCe) and incorporating limited a priori geological information available for the area around each station and the estimated averaged eHVSRs were used in an 1D inversion framework to determine the best-fit velocity profiles down to the seismological bedrock. However, for certain stations where the inversion process could not be satisfactorily completed, alternative methods such as Multichannel Analysis of Surface Waves (MASW) and other geophysical measurements were utilized to obtain shear wave velocity profiles. The reliability of these velocity models was assessed by comparing them with existing profiles obtained from independent geophysical and geotechnical prospecting. Through this characterization, strong-motion databases such as the ESM db are enhanced in terms of metadata, allowing accelerometer recordings to be utilized in their full potential for engineering and seismological applications. The proposed methodology is demonstrated to be applicable in a broader

Β.2

Εκτίμηση ισχυρής σεισμικής δόνησης μεγάλων σεισμών στον Ελληνικό χώρο: Η περίπτωση του καταστρεπτικού σεισμού (Μ7.2) της Κεφαλονιάς1953

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ΠΕΡΙΛΗΨΗ
Κατά τον 20ο αιώνα, πριν την ανάπτυξη σεισμολογικών δικτύων (σεισμογράφων,επιταχυνσιογράφων) στη χώρα, συνέβησαν μεγάλοι σεισμοί (Μ>7.0) οι οποίοι σε πολλές των περιπτώσεων προκάλεσαν μεγάλες βλάβες στο δομημένο περιβάλλον και απώλειες ανθρωπίνων ζωών. Μεταξύ τέτοιων γεγονότων είναι και ο μεγάλος σεισμός (Μ7.2) στις 12/8/1953 στην Κεφαλονιά, κατά τον οποίο καταστράφηκε ολοσχερώς η πλειονότητα των οικισμών του νησιού καθώς και οικισμών της Ζακύνθου και Ιθάκης. Βλάβες παρατηρήθηκαν και στην Ηλεία και Αιτωλία, ενώ ο σεισμός έγινε αισθητός και
στη Νότια Ιταλία (Παπαζάχος και Παπαζάχου, 2002). Οι μεγαλύτερες μακροσεισμικές εντάσεις (IXX) παρατηρήθηκαν στο Αργοστόλι, Ληξούρι, Ασπρογέρακα και Χαβδάτα. Η τρωτότητα των κτιρίων που επλήγησαν από το σεισμό του 1953 κατά γενική ομολογία ήταν εντελώς διαφορετική (υψηλότερη) από αυτή των σημερινών κτιρίων κυρίως λόγω του γεγονότος ότι δεν είχαν σχεδιασθεί με αντισεισμικό κανονισμό. Ωστόσο, η σφοδρότητα της σεισμικής δόνησης και η έκταση της, δεν αφήνουν αμφιβολία ότι επρόκειτο για σεισμό ο οποίος ακόμη και σήμερα θα μπορούσε να προκαλέσει μεγάλες μακροσεισμικές εντάσεις στην ευρύτερη περιοχή οδηγώντας σε υψηλή σεισμική διακινδύνευση του δομημένου περιβάλλοτος και σε ζωτικές υποδομές της περιοχής. Στην εργασία αυτή, επιχειρείται ηαιτιοκρατική προσομοίωση της ισχυρής σεισμικής δόνησης ενός σεναρίου σεισμού ανάλογου με εκείνον του 1953 (Μ7.2) και εκτιμάται η κατανομή της στα νησιά της Κεφαλονιάς, Ιθάκης και Ζακύνθου σε όρους μέγιστης εδαφικής επιτάχυνσης (PGA), ταχύτητας (PGV) και φασματικής επιτάχυνσης (PSA) για επιλεγμένες ιδιοπεριόδους. Πριν την προσομοίωση, επιχειρείται τεκμηρίωση της ακολουθούμενης μεθοδολογίας με βάση τις ενόργανες καταγραφές επιταχυνσιογράφων του πρόσφατου σεισμού στις 26/1/2014 στην Κεφαλονιά (Μ6.1). Τα αποτελέσματα της τεκμηρίωσης υπήρξαν ενθαρρυντικά για την εφαρμογή της μεθοδολογίας και στο σεισμό του 1953. Για το σκοπό αυτόν, αξιοποιείται η γνώση των σεισμοτεκτονικών χαρακτηριστικών των πιθανών τμημάτων ρηγμάτων που έδρασαν κατά το σεισμό και εισάγονται οι σχετικές αβεβαιότητες στις εκτιμήσεις (μέγεθος σεισμικής ροπής, γεωμετρία ρήγματος, κτλ.). Επίσης, αξιοποιούνται πρόσφατα μοντέλα πρόβλεψης ισχυρής εδαφικής κίνησης που προτάθηκαν για τον Ελληνικό χώρο με τις αβεβαιότητες που εμπεριέχουν. Τα αποτελέσματα των προσομοιώσεων για σεισμό μεγέθους σεισμικής ροπής, Mw ~7.2, δίνουν υψηλές τιμές PGA (>0.42g) σε συνθήκες βραχώδους υποβάθρου (Vs30 = 800 m/s2) σχεδόν σε ολόκληρο το νησί της Κεφαλονιάς, το οποίο καλύπτεται σχεδόν εξ ολοκλήρου από την προβολή της επιφάνειας του υπό εξέταση ρήγματος. Οι τιμές PGA στο βόρειο τμήμα της Κεφαλονιάς καθώς και στο δυτικό της, κυμαίνονται μεταξύ 0.24 - 0.42 g, για βραχώδες υπόβαθρο. Χαρακτηριστικές είναι οι τιμές της PGA που εκτιμώνται στο Αργοστόλι (~0.43 g) και Ληξούρι (0.40 g).
Οι τιμές αυτές της PGA, σε συνδυασμό με καμπύλες τρωτότητας των υφιστάμενων κτιρίων ή/και ζωτικών υποδομών μπορούν να οδηγήσουν στην εκτίμηση της σεισμικής_

B.3

ΠΣΑΜΤΣ
ΑΘΗΝΑ 30, 31 ΟΚΤ, 1 ΝΟΕ 2025

Δίκτυο Επιταχυνσιογράφων εντός Πολεοδομικού Συγκροτήματος και Συμβολή στη Μείωση της Σεισμικής Διακινδύνευσης

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ΠΕΡΙΛΗΨΗ
Η ταχεία εκτίμηση της σεισμικής δόνησης εντός πολεοδομικού ιστού μετά από ισχυρό σεισμόαποτελείκαθοριστικό παράγοντα άμεσης εκτίμησης των αναμενόμενων βλαβών στο δομημένο περιβάλλον καιτης οργάνωσης για αποτελεσματική απόκριση των αρμοδίων φορέων(πολιτική προστασία, τεχνικέςυπηρεσίες αυτοδιοίκησης κτλ.) με κατάλληλες παρεμβάσεις για μείωση των συνεπειών του σεισμού .Για το σκοπό αυτόν απαιτείται εγκατάσταση πυκνού δικτύου επιταχυνσιογράφων σε κατάλληλα επιλεγμένες θέσεις του πολεοδομικού συγκροτήματος. Το υψηλό κόστος οργάνων και ο ασφαλής τρόπος μετάδοσης των δεδομένων από τη θέση εγκατάστασης σε Υπολογιστικό Κέντρο, αποτελούν περιοριστικούς παράγοντες για την ανάπτυξη τέτοιων δικτύων. Λαμβάνοντας υπόψη τους παραπάνω περιορισμούς, επιλέχθηκε χαμηλού κόστους επιταχυνσιογράφος (Low Cost Accelerometer: LCA), ελληνικού σχεδιασμού και κατασκευής (Seismobug, www.seismobug.com), υψηλής ανάλυσης (20bits), με χαμηλό επίπεδο ηλεκτρονικού θορύβου (RMS<0.1mg). Ακολούθησε εγκατάσταση ενός LCA στην ίδια θέση με επιταχυνσιογράφο ευρέως φάσματος, υψηλής ανάλυσης (Episensor, 24bits) και εμπορικά διαθέσιμου με κόστος ~2 τάξεις μεγέθους ακριβότερου από το LCA, στο δίκτυο ARGONET στην Κεφαλονιά. Δημιουργήθηκε βάση καταγραφών επιταχυνσιογράφων των 2 οργάνων πλέον των 100 σεισμών, η σύγκριση των οποίων έδειξε την αξιοπιστία του LCA για την περιοχή συχνοτήτων ενδιαφέροντος μηχανικού. Στη συνέχεια, ως θέσεις εγκατάστασης επιλέχθηκαν κτίρια σχολικών μονάδων που κατά τεκμήριο κατανέμονται ομοιόμορφα εντός του πολεοδομικού συγκροτήματος και διαθέτουν διαδικτυακή υποδομή για μεταφορά των δεδομένων σε πραγματικό χρόνο. Η υλοποίηση της παραπάνω προσέγγισης έγινε σε 3 πιλοτικές θέσεις της χώρας. Συγκεκριμένα, σε 31 σχολικές μονάδες στη Θεσσαλονίκη, σε 5 στην Αλεξανδρούπολη, και 5 στη Σάμο. Τα πρώτα αποτελέσματα από σεισμούς μικρού μεγέθους που κατέγραψαν τα δίκτυα των LCA, αναδεικνύουν τη συμβολή τους στην αξιόπιστη και ταχεία εκτίμηση της σεισμικής δόνησης, συμβάλλοντας ουσιαστικά στη λεπτομερή εκτίμηση των χαρτών αισθητότητας (Shakemaps), ιδίως σε περιπτώσεις πολεοδομικών συγκροτημάτων της χώρας. Η χρήση λεπτομερών χαρτών αισθητότητας σε πραγματικό χρόνο, σε συνδυασμό με τις καμπύλες τρωτότητας του δομημένου περιβάλλοντος, μπορεί να συμβάλει στην ταχεία εκτίμηση κατανομής βλαβών εντός του συγκροτήματος, ως καθοριστικό εργαλείο στη λήψη αποφάσεων παρέμβασης της πολιτείας για μείωση των συνεπειών ισχυρού σεισμού.

B.4

Αξιολόγηση της κατηγοριοποίησης των εδαφικών συνθηκών και των παραγόντων ενίσχυσης του Ευρωκώδικα 8

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ΠΕΡΙΛΗΨΗ
Οι παράγοντες φασματικής ενίσχυσης (Site Amplification Factors: SAFs) της σεισμικής εδαφικήςκίνησης αποτελούν καταλυτικό παράγοντα για την εκτίμηση της σεισμικής επικινδυνότητας σε μιαθέση, επηρεάζοντας τόσο τον αντισεισμικό σχεδιασμό όσο και την αξιολόγηση της συμπεριφοράς των κατασκευών κατά τη διάρκεια ενός σεισμού. Ο ευρωπαϊκός αντισεισμικός κανονισμός, Ευρωκώδικας 8 (EC8), καθορίζει παράγοντες ενίσχυσης με βάση την κατηγοριοποίηση των εδαφικών συνθηκών, χρησιμοποιώντας στην ισχύουσα έκδοσή του τη μέση ταχύτητα των εγκαρσίων κυμάτων στα επιφανειακά 30 μέτρα (Vs30), ενώ στην επικαιροποιημένη έκδοση του 2024, λαμβάνονται υπόψη επιπλέον γεωτεχνικές και γεωφυσικές παράμετροι. Στην παρούσα μελέτη, 151 θέσεις σταθμών επιταχυνσιογράφων στην Ελλάδα κατηγοριοποιήθηκαν σύμφωνα με τα κριτήρια του Ευρωκώδικα 8, τόσο της ισχύουσας όσο και της επικαιροποιημένης έκδοσής του, με βάση τις αντίστοιχες παραμέτρους. Για τις ίδιες θέσεις, οι SAFs υπολογίστηκαν μέσω της τεχνικής Γενικευμένης Αντιστροφής (Generalized Inversion Technique: GIT), με προσαρμογή των φασμάτων Fourier (Fourier Amplitude Spectra: FAS) σε δύο θέσεις αναφοράς, οι οποίες αντιστοιχούν σε συνθήκες βραχώδους υποβάθρου (Vs = 800m/s). Η προσαρμογή πραγματοποιήθηκε με βάση τις καμπύλες ενίσχυσης της σεισμικής κίνησης από το βραχώδες υπόβαθρο στην επιφάνεια όπως προτάθηκαν από Ευρωπαϊκά δεδομένα επιταχυνσιογράφων (Shible et al. 2025). Στη συνέχεια, οι SAFs μετατράπηκαν σε παράγοντες φασμάτων απόκρισης φασματικής επιτάχυνσης (PSA, 5% damped), χρησιμοποιώντας τον ενίσχυσης. Παράλληλα υποδεικνύουν την ανάγκη ενσωμάτωσης γεωφυσικών δεδομένων επιπλέον θέσεων επιταχυνσιογράφων σε ορισμένες κατηγορίες, ιδίως της επικαιροποιημένης εκδοσης του EC8. λόγο [PSA/FAS], που προέκυψε από την Ευρωπαϊκή βάση δεδομένων. Εφόσον κάθε θέση κατηγοριοποιήθηκε σε μια κατηγορία του Ευρωκώδικα 8, οι SAFs του παράγοντα φασματικής απόκρισης της PSA συγκρίθηκαν με τους παράγοντες ενίσχυσης που προτείνονται από τον Ευρωκώδικα 8 τόσο της ισχύουσας όσο και της επικαιροποιημένης έκδοσής του. Η σύγκριση αυτή έδειξε ικανοποιητική συμφωνία για τις κατηγορίες A, B και C, ενώ σημαντικές αποκλίσεις παρατηρήθηκαν στις κατηγορίες D, E και F, γεγονός που αντικατοπτρίζει την ύπαρξη τοπικών διαφοροποιήσεων στην εδαφική απόκριση. Τα ευρήματα της μελέτης υπογραμμίζουν τηνικανοποιητική συμφωνία αλλά και τους περιορισμούς των υφιστάμενων κατηγοριοποιήσεων των παραγόντων φασματικής ενίσχυσης κατά Ευρωκώδικα 8 στην αποτύπωση των τοπικών φαινομένων.

C.1

Okullarda Yerbilimlerine İlgiyi Artırmak İçin Örnek Uygulama "Okul Sismolojisi"

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Bilindiği gibi ülkemizde yerbilimlerine olan ilgi 1999 Marmara depremlerinin yaratmış olduğu hasar ve can kaybı sonucunda ilgili kamu kurumları, yerel yönetimler ve özel sektörün eksikliklerini tamamlama çabaları sonucunda gelişmiştir. Maalesef her büyük deprem sonucunda yerbilimlerine ilgi artmış suskun dönemlerde bu ilgi azalmıştır. Geleceğimize yön verecek, şekillendirecek olan gençliğimizin yerbilimlerine olan ilgisini artırmak, afet ve acil durumlarla ilgili farkındalığını geliştirmek amacıyla yurtdışında da uygulanan "okul sismolojisi" konusu Türk-Yunan ortaklığında başlatılan "Depreme Dirençli Okullar-EReS" projesi kapsamında gerçekleştirilmiştir. EReS projesinin genel amacı afet yönetiminde önemli bir yeri olan kritik tesislerden eğitim kurumlarının (okulların) gerek fiziksel açıdan (yapısal olarak) gerekse yaşayanlar (öğretmenler, öğrenciler, idari personel) açısından depreme dirençli hale getirebilmektir. Proje kapsamında Çanakkale ve İzmir illerinde farklı jeolojik birimlerde seçilen toplam 12 okula düşük maliyetli MEMS sensör olarak adlandırılan ivme ölçerler yerleştirilmiştir. Bu sensörlerden sürekli veriler alınmakta ve değerlendirilmektedir.

Okul Sismolojisi kavramının temel amacı özellikle orta öğretim çağındaki öğrencilere yerbilimlerinin deprem konusunda ilgili bilim dalları olana jeoloji ve jeofizik mühendisliklerini tanıtmak, sevdirmek ve meslek seçimlerinde bu bilim dallarına tercih yapmalarını sağlamaktır. Bu amaca ulaşmak için deprem ve afet konusunda verilen temel bilgilerle farkındalıklarını artırmak, okullarında kurulan deprem ölçüm cihazlarından gelen verilerin kabaca ne ifade ettiğini, nasıl değerlendirildiğini ve sonuçlarıyla ne yapılması gerektiği çok basitçe anlatılarak hedefe varılması planlanmıştır. Ayrıca bu eğitimi alan öğrencilerin ülkemizde çeşitli Ar-Ge destekli projelere, yarışma ve festivallere katılması içinde gerekli yönlendirmeler yapılmıştır. Bu amaçla proje kapsamında Çanakkale ve İzmir illerinde öncelikle afet farkındalığını artırmak için İl AFAD Müdürlüklerinin desteğiyle farkındalık eğitimleri verilmiş, sonra okul sismolojisi kapsamında ilgili uzmanlar tarafında özellikle coğrafya öğretmenlerine ve seçilen öğrencilere jeoloji ve jeofizik mühendisliği tanıtılmış, deprem konusunda temel kavramlar öğretilmiş ve okullarında bulunan deprem cihazlarından gelen verilerin değerlendirilmesi gösterilmiştir. Bir deprem anında eğitim alan bu öğrencilerden deprem verisini değerlendirmeleri ve okullarındaki kriz yönetimi aşamasında söz sahibi olmaları beklenmektedir.

Sonuç olarak "okul sismolojisi" yurtdışında yaygınlaşan ancak ülkemizde ilk örnekleri henüz yeni ortaya çıkan bir kavram olup meslek seçiminde hedef kitle olan öğrencilerimizin yerbilimlerine olan ilgisini artırmak açısından önemli bir çalışmadır. Okul binasının deprem sonrası yapısal açıdan durumunu da ortaya koyan bu sistem okullarımıza kurulacak bir veya iki adet deprem ölçüm cihazı ve standart eğitim dokümanlarıyla ülkemizde yaygınlaştırılması kolay ve düşük maliyetli bir çalışma olacaktır.

C.2

Okulları Depreme Dirençli Hale Nasıl Getiririz?

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AFAD Başkanlığı deprem zararlarının azaltılması kapsamında 2023 yılında Türk-Yunan ortaklığında Earthquake Resilient Schools (EReS) – Depreme Dirençli Okullar adlı bir Avrupa Birliği destekli proje başlatmıştır. Projede ülkemiz sınırları içinde Çanakkale ve İzmir illeri, Yunanistan tarafında ise Dedeağaç ve Sisam adası pilot olarak seçilmiştir.

EReS projesinin genel amacı afet yönetiminde önemli bir yeri olan kritik tesislerden eğitim kurumlarının (okulların) gerek fiziksel açıdan (yapısal olarak) gerekse yaşayanlar (öğretmenler, öğrenciler, idari personel) açısından depreme dirençli hale getirebilmektir. Bilindiği gibi ülkemiz bir deprem ülkesi olup geçmişten günümüze kadar çok sayıda hasar ve can kaybına neden olan birçok deprem olayıyla karşı karşıya kalınmıştır. Sınır ötesi komşularımızdan biri olan Yunanistan'ın da benzer şekilde Ege Denizi'nde deprem üreten faylardan dolayı deprem tehlikesi vardır. Deprem zararlarının azaltılması kapsamında kritik tesisler arasında en önemlilerinden birisi de okullardır. Afet öncesi eğitim kurumlarında faaliyet gösteren bireylerin depreme/afete karşı eğitimlerinin sağlanması, farkındalığının oluşturulması, bu yapıların deprem olayına karşı daha güvenilir hale sokulması, kriz anında da bu kritik tesislerin durumunun acilen ortaya konması, kriz yönetiminde kullanılabilirliğinin belirlenmesi kurulacak sistemlerle sürekli gözlem altında tutulması ve müdahale sistemlerinin ulusal ve uluslararası modellerle araştırılması EReS projesinin temel gerekçeleridir. Projenin hedef aldığı kesim öncelikle okullarda öğretmenler, öğrenciler, idari personel ile kriz yönetiminde rol alan afet ve acil durum yöneticileridir.

Proje kapsamında günümüze kadar seçilen pilot illerde farklı zemin koşullarında olmak koşuluyla 12 adet okul belirlenmiş ve bu okulların giriş veya bodrum katı ile en üst katına uygun maliyetli MEMS sensörler yerleştirilmiş ve veriler alınmaya başlamıştır. Okullarımızda farkındalığı artırmak ve "okul sismolojisi" konusunda ülkemizde bir ilki gerçekleştirmek amacıyla gerek Çanakkale ve İzmir İl AFAD Müdürlüklerinin eğitim şubeleri gerekse başkanlığımızdan konuyla ilgili uzmanların katılımıyla eğitimler düzenlenmiştir. Ayrıca her iki ilimizde de konuyla ilgili çalıştaylar planlanmıştır. Sonuç olarak ülkemiz genelinde 100 binin üzerinde okul olduğu varsayılırsa bu okulların önemli bir kısmının da yapısal olarak deprem dayanıklılıklarının belirsizliğini koruduğu düşünülürse buralarda öğrenim gören gençlerimizin ve öğretmenlerimizin depreme karşı bilinç seviyelerinin arttırılması, yapıların bir deprem anında durumunun ivedilikle ortaya konması, kriz yönetimine net bilgilerin aktarılması afet yönetiminin önemli bileşenlerindendir. Bu tarz proje çalışmaları ve metotların ülkemizde yaygınlaştırılması gereklidir. Okulları depreme dirençli hale getirmek için yapısal olarak deprem gözlem cihazları ile 7/24 izlemeli, okuldaki bireylerin deprem konusunda bilinçlenmesini artırmalı ve planlarımızı yaparak sürekli tatbikatlarla deprem olayına hazır olmalıyız.

D.1

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Estimation of Vertical Amplification Correction Function (VACF) in Greece based on the Generalized Inversion Technique of Strong Motion and Diffuse Field Concept on Earthquakes

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Key Points:

- A method is presented and implemented to correct the horizontal-to-vertical spectral ratio of earthquakes (eHVSR) to obtain horizontal site amplification factors.
- The Vertical Amplification Correction Function is obtained using the generalized inversion technique to correct the eHVSRs in Greece.
- Site amplification from the seismological bedrock to surface is provided within the 0.3–15 Hz frequency range.

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Abstract

The main purpose of this study is the estimation of Site Amplification Factors (SAFs) of horizontal component of the ground motion to improve seismic hazard assessment, as these factors play an important role in seismic site response. Towards this effort, the subsurface structure and the related amplification effects of two accelerometer stations in Greece were acquired, examining their use as reference stations. This was achieved by computing the Vertical-to-Horizontal spectral ratio corresponding to the depth of the seismological bedrock and comparing it with the theoretical value of ~ 0.76 for seismological reference stations, according to the Diffuse Field Concept for earthquakes, DFCe, in case of a Poisson solid. Thereafter, the two selected reference stations were used to invert for horizontal and vertical SAFs for a total of 151 accelerometer stations in Greece. The vertical SAFs for each site was used to estimate a mean representative Vertical Amplification Correction Functions (VACFs) in Greece. These VACFs can be used for assessing horizontal SAFs based on horizontal-to-vertical ratio of earthquake, where it is available, contributing thus to site specific seismic hazard assessment in regions where there is lack of observed classical amplification spectral ratios with an adjacent surface or borehole reference site. Simulated horizontal SAFs were calculated for sites out of the examined dataset for the frequency range 0.3-15 Hz, in order to evaluate the effectiveness of the proposed VACFs.