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EARTHQUAKE RESILIENT SCHOOLS

European Commission

A framework for data & information exchange for seismic risk harmonization in the Greece-Türkiye Cross Border Area

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WP3: Joint Seismic Risk Assessment of School Buildings

T3.1: A framework for information exchange for seismic risk harmonization in the Greece-Türkiye CBA

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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 WP3: Joint Seismic Risk Assessment of School Buildings and is related to T3.1: A framework for information exchange for seismic risk harmonization in the Greece-Türkiye CBA

1.2 SCOPE AND OBJECTIVES

The scope of this document is to outline the activities carried out within the framework of Task 3.1 aimed at accomplishing the project objectives. These efforts are ultimately geared towards attaining the Specific Objective of "Risk Assessments" as stipulated by the funding Programme under the Call "Prevention and Preparedness Projects on Civil Protection and Marine Pollution (UCPM-2022-PP)."

In pursuit of this goal, the present deliverable places emphasis on the following project objectives:

- Establishing collaborative data and information sharing through a Rapid Earthquake Damage Assessment (REDA) platform.
- Harmonizing procedures for seismic risk assessment in areas of high seismicity within the Greek & Turkish Cross Border Area (CBA).
- Leveraging the outcomes of the EU-funded project REDACt (*https://www.redact-project.eu/*) and employing a shared tool/system for the collaborative processing and sharing of data and information (with potential modifications or additions as required).

2 OVERVIEW OF SEISMIC VULNERABILITY ASSESSMENT METHODOLOGIES FOR SCHOOL BUILDINGS

The structural safety of school infrastructure against natural and manmade hazards is prerequisite to ensure a safe environment for children's learning activities. It is a high priority on the agenda of the UN Office for Disaster Risk Reduction (UNDRR), and it is reflected in the structure of the recently revised Comprehensive School Safety (CSS) framework (GADRRRES 2022). The CSS framework has been formulated to achieve the education sector targets set out by the Sendai Framework for Disaster Risk Reduction (SFDRR) 2015-2030 (UNDRR, https://www.undrr.org/publication/sendai-framework-disaster-risk-reduction-2015-2030).

It is outside the scope of the present project to compile a comprehensive worldwide state-of-the-art overview on the seismic safety of school buildings, hence only some representative research efforts are herein mentioned, indicative of the various research topics under investigation.

The World Bank, through its Global Program for Safer Schools (GPSS), aims to encourage large-scale investments to improve the disaster safety and resilience of school infrastructure. Within the GPSS program, a Roadmap for Safer and Resilient Schools (RSRS) was produced, and as an essential technical foundation for the RSRS, the Global Library of School Infrastructure (GLOSI), was developed by University College London, UK, and Universidad De Los Andes, Colombia, and is freely available online (The World Bank 2022, https://gpss.worldbank.org/en/glosi).

GLOSI provides a repository of evidence-based knowledge and statistics on school infrastructure, quantitative metrics evaluating the performance of school buildings affected by natural hazards, and scalable solutions to improve their resilience. The GLOSI framework includes a comprehensive methodological approach including data collection, classification using the GLOSI taxonomy, seismic analysis for fragility and vulnerability assessment to underpin location specific risk assessment studies. Based on the analysis of a wide collection of school building types, the GLOSI repository includes a library of fragility and vulnerability functions as well as risk reductions solutions for 38 commonly found school *index buildings* (Fernandez et al, 2022, Adhikari et al. 2023). It should be noted that GLOSI is mainly based on school databases from developing countries (Peru, Nepal, Philippines, El Salvador, Dominican Republic, Colombia (Cali municipality), Kirgiz Republic and India (city of Guwahati)) and is hence primarily oriented in dealing with the particular structural characteristis of the school buildings in these countries (the majority being masonry buildings, and many of poor seismic capacity, built without any conformity to seismic codes).

The importance of seismic safety of school buildings is evidently even more recognized in developed countries, and several research efforts are increasingly dealing with the subject worldwide. In USA, the Earthquake Engineering Research Institute (EERI) supports the School Earthquake Safety Initiative (SESI), which led to the seismic screening of school buildings in various US states (EERI Staff et al., 2016). In the framework of SESI, an Earthquake Performance Assessment Tool (EPAT) was also developed and was implemented at a first stage for schools in the state of Washington. The tool is designed to provide a preliminary, but quantitative, determination of the level of seismic risk for school buildings and aims to provide technical data about the seismic vulnerability of a district's buildings so that the district can systematically prioritize retrofit or replacement of buildings with the highest level of seismic risk (Goettel et al, 2017).

It should be noted that due to economic constraints, a very small fraction of the existing school building stock has actually been upgraded in the frame of pre-earthquake strengthening programmes world-wide. Until recently, the most extensive efforts in implementing school strengthening programmes were made in Japan, and some interesting examples of such applications are presented in Japan Ministry of Education (2006). A rough estimate of the seismic risk of the schools in 14 countries of the Andean region and Central America, is presented in ERN (2010). Also, an indicative evaluation of the benefits of the reduction of the structural vulnerability of those facilities are presented in the document.

In Europe, the problem is more intense in the more earthquake-prone SE European countries (especially Italy, Greece, Türkiye, Cyprus and several Balkan countries), in which extensive damage to school buildings has been observed during past earthquakes and there is a need to better understand their potential vulnerability. Among others, O'Reilly et al (2018) present an analytical methodology to reliably quantify the expected annual loss due to damage of Italian school buildings, through numerical investigations of the seismic behaviour of three buildings representative of the Italian school building stock.

A methodology for the quick identification of the most vulnerable school buildings in urban areas of Greece is proposed by Karatzetzou et al (2022). It involves a two-level ranking process, which allows the prioritization for more detailed investigations of the schools with the smallest seismic capacity. The proposed methodology was applied to the school buildings of the municipality of Thessaloniki, Greece, indicating that that about 3.5% of the total studied school buildings may require further investigation for retrofitting and strengthening.

In Cyprus, after a series of earthquakes that occurred between 1995 and 1999, it was decided to carry out a seismic retrofitting of all school buildings. A numerical investigation of the effectiveness of the retrofitting schemes is presented in Chrysostomou et al. (2015). Non-linear analysis is conducted on calibrated analytical models of two selected buildings (a RC and a masonry one) and fragility curves are derived for typical reinforced concrete and unreinforced masonry structures. These curves are then used to carry out a feasibility study, including both benefit-cost and life-cycle analysis, and evaluate the effectiveness of the proposed strengthening programme.

In the Eastern Mediterranean area, earthquakes pose also a major risk for schools also in Turkey. Inel et al. (2008a,b) investigated the seismic performance of RC school buildings through pushover analyses of six template designs, representative of a major percentage of school buildings in medium-size cities located in high seismic region of the country. Seismic performance evaluation was carried out in accordance with the at the time recently published Turkish Earthquake Code. The effects of material quality on the seismic performance of school buildings were investigated and a detailed examination of capacity curves and performance evaluation identified deficiencies and possible solutions for the examined template designs. The performance of school buildings due to the recent catastrophic M7.7 and M7.6 events of February 6, 2023 in the SE part of the country is presented in Ozturk et al. (2003). Observed (through field investigations) damage types and causes of damage in school buildings are presented, and the observations are supported through performance-based analytical investigations of two types of design projects.

It should be noted that although country-specific investigations on the seismic vulnerability of school buildings have been pursued for several years world-wide, the particular scope of the ERES project, i.e., the harmonization of the seismic hazard and risk of such buildings among neighboring countries is much less investigated and has only recently gained momentum. To the research team's knowledge, only one similarly-oriented project has been until now emplemented in Europe (project PERSISTAH, focusing on the existing primary schools in the Algarve (Portugal) and Huelva (Spain) regions, presented in Estêvão et al. (2022)).

The challenges in the present ERES project have a higher degree of difficulty, since the cross-border area between Greece and Turkye presents a definitely higher seismicity, and the seismic vulnerability of schools of all grades (not only primary) will be investigated. An advantage of the ERES project is that it will be based on the already fruitful results of the REDACt project and further elaborate the developed harmonization methodologies with an orientation on school buildings. Especially regarding the harmonized approach towards the seismic vulnerability of schools, the experience of the research team obtained within the framework of the REDACt project, having developed tools that used the Global Earthquka Model Taxonomy (Brzev et al., 2013) along with the Martins-Silva (2021) fragility curves may serve as a basis for further investigations and elaborations taking into account possible structural characteristics particular to school buildings.

Ersin (2010) investigated the seismic performance of different types of reinforced concrete school buildings with using Japan Seismic Index Method (J.S.I.M) in different levels of evaluation. In the study, some other seismic performance evaluation methods are also mentioned such as ATC 21 and FEMA 310 explained in detail in order to have a chance to compare the advantages and disadvantages. The reinforced concrete existing school buildings are evaluated in 1st and 2nd levels of evaluations with using J.S.I.M. The results of these evaluations are not only compared within each level of screeening but also with the results of nonlinear static pushover analyses results of the same buildings according to the regulations of the then-current Turkish Earthquake Code 2007.

3 STRUCTURAL PROPERTIES OF SCHOOL BUILDINGS IN GREECE

3.1 AVAILABLE DATASETS

The accuracy of results in any risk assessment scenario is significantly influenced by the quality and accessibility of reliable exposure data. In the case of Greece's school building stock information in the Cross Border Area of Greece and Türkiye, the research team relied on the two currently available datasets.

- The first one comprises information obtained from the 2011 National Census conducted by the Hellenic Statistical Authority (www.statistics.gr), as the 2021 Census data are not yet available. The research team had previously acquired comprehensive data for the Central Macedonia and Eastern Macedonia & Thrace Regions, situated within the scope of the REDACt project, which includes the pilot case site of Alexandropoli. Although the corresponding data for the North Aegean Region (where Samos is located) were also requested, we have not received them as of the time of writing this document.
- The second dataset, sourced from the public agency Ktiriakes Ypodomes S.A. (KT.YP., https://www.ktyp.gr), provides highly detailed information. It was compiled by qualified civil engineers utilizing a rapid visual screening approach; however, it covers only a restricted number of school buildings.

3.1.1 The ELSTAT database

In the context of our team's involvement in ongoing research projects over the past years, such as ERES and REDACt, we have submitted requests to the

Hellenic Statistical Authority for data pertaining to each individual building. This request covers all buildings in the capitals of the former Prefectures within the Central Macedonia, Eastern Macedonia & Thrace, and North Aegean Regions. Additionally, we have sought building data for each settlement in rural areas. As previously mentioned, data for the first two regions have already been acquired, while we are awaiting approval for the latter. Furthermore, we were provided with cartographic backgrounds (shapefiles) per Municipality, delineating building blocks and census sectors. It's important to note that the available data only include building numbers, with no accompanying information on the built-up area. Population data for each building block have also been received.

The buildings in the area were matched to typical categories based on the characteristics that affect their seismic vulnerability, adopting the classification proposed by the Global Earthquake Model Foundation. Specifically, the buildings were classified based on the following characteristics:

- Construction material (e.g., reinforced concrete, steel, masonry, etc.);
- Building height (number of storeys);
- Construction period (corresponding to the seismic design level in compliance to the national seismic code in force at the time);
- Existence of irregularity in height (e.g., soft storey (pilotis));

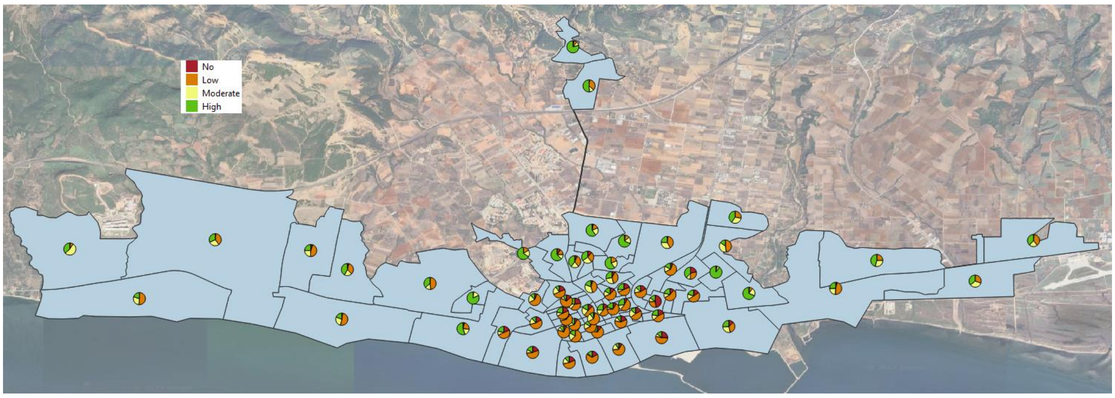


Figure 1. Spatial distribution of the building stock in Alexandroupoli, in terms of seismic design level (No: <1959, Low: 1960–1984, Moderate: 1985–1995, High: >1996)

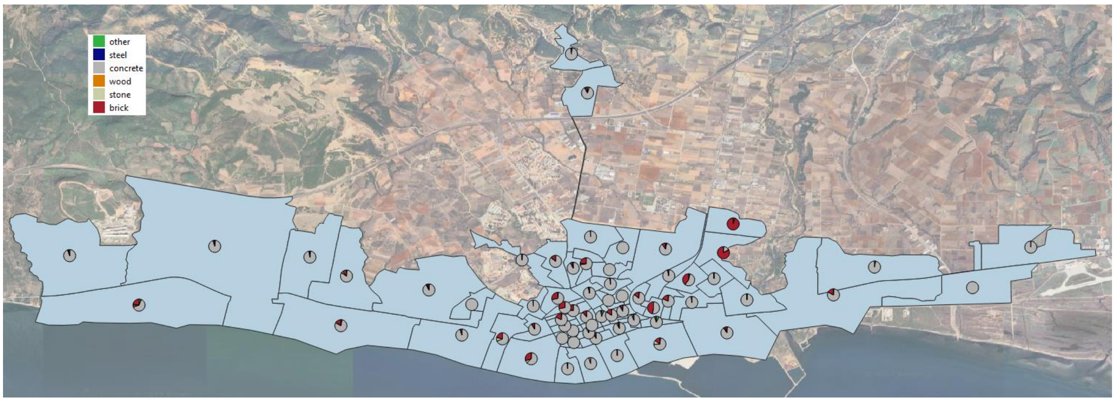


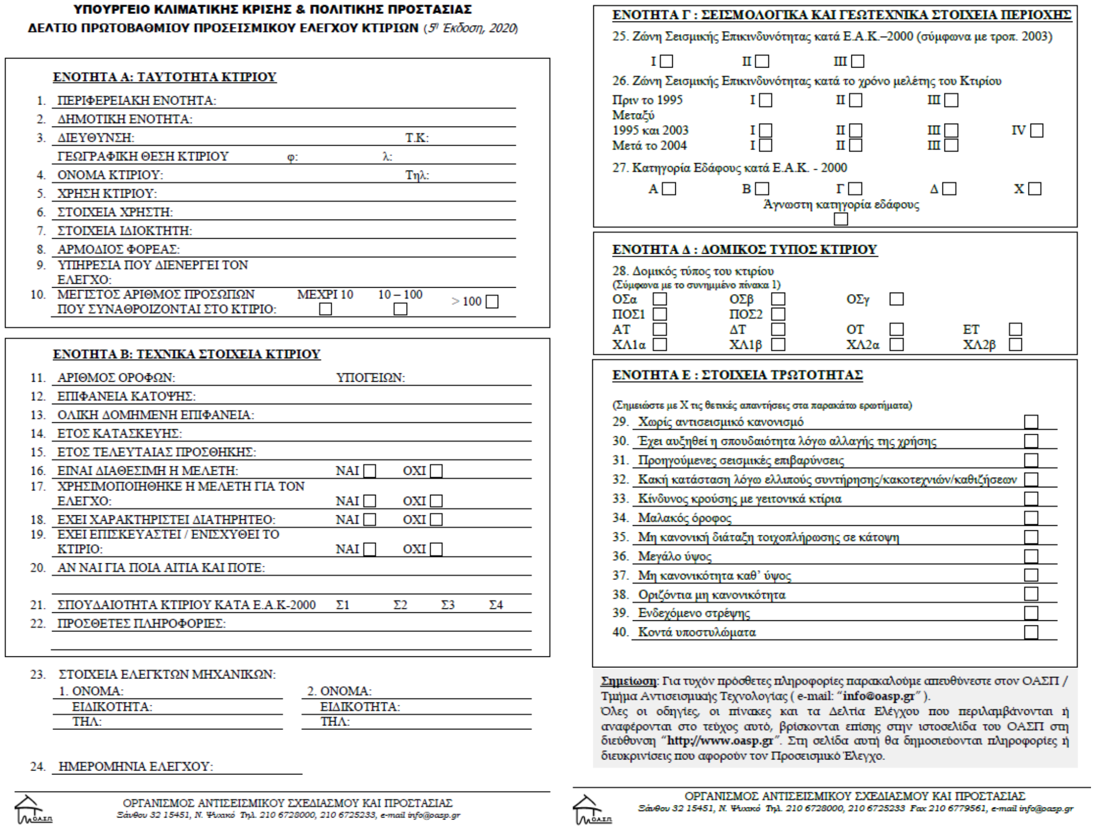
Figure 2. Spatial distribution of the building stock in Alexandroupoli, in terms of construction material

The database also encompasses information about the usage of the buildings, indicating whether they are residential, commercial, school facilities, etc. This allowed us to specifically identify the school buildings included in this study. Examples of the spatial distribution of the building stock are presented in Figure 1 and Figure 2 for the pilot case site of Alexandroupoli. Filtering this database to focus exclusively on school buildings yields the contents outlined in section 3.2.1.

3.1.2 The KT.YP. database

Ktiriakes Ypodomes S.A. is Greece's sole authority for delivering the country's public building infrastructures, such as schools, hospitals, courts of justice, correctional facilities, embassies, fire stations, and any other public building that may be required.

The data provided by KT.YP. were collected in 2005 in Alexandroupoli and Samos using a Rapid Visual Screening (RVS) procedure recommended by the Earthquake Protection & Planning Organization (EPPO; the latest version is available at https://www.oasp.gr/node/74). This dataset was developed by qualified civil engineers and includes information for 25 schools in Samos, constructed before 1985 (No or Low code design level), and 14 schools in Alexandroupoli, built prior to 1959 (No code). It is important to note that each record in the dataset may pertain to any type of statically independent building within each school complex, encompassing different activilties such as classrooms, gyms, storage facilities, toilets etc.


ΥΠΟΥΡΓΕΙΟ ΚΛΙΜΑΤΙΚΗΣ ΚΡΙΣΗΣ & ΠΟΛΙΤΙΚΗΣ ΠΡΟΣΤΑΣΙΑΣ
ΔΕΛΤΙΟ ΠΡΩΤΟΒΑΘΜΙΟΥ ΠΡΟΣΕΙΣΜΙΚΟΥ ΕΛΕΓΧΟΥ ΚΤΙΡΙΩΝ (5η Έκδοση, 2020)

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    2. ΟΝΟΜΑ: ΕΙΔΙΚΟΤΗΤΑ: ΤΗΛ:
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26. Ζώνη Σεισμικής Επικινδυνότητας κατά το χρόνο μελέτης του Κτιρίου
    Πριν το 1995 I ☐ II ☐ III ☐
    Μεταξύ 1995 και 2003 I ☐ II ☐ III ☐ IV ☐
    Μετά το 2004 I ☐ II ☐ III ☐
27. Κατηγορία Εδάφους κατά Ε.Α.Κ. - 2000
    Α ☐ Β ☐ Γ ☐ Δ ☐ Χ ☐
    Άγνωστη κατηγορία εδάφους ☐

ΕΝΟΤΗΤΑ Δ : ΔΟΜΙΚΟΣ ΤΥΠΟΣ ΚΤΙΡΙΟΥ

28. Δομικός τύπος του κτιρίου
    (Σύμφωνα με το συνημμένο πίνακα 1)
    ΟΣα ☐ ΟΣβ ☐ ΟΣγ ☐
    ΠΟΣ1 ☐ ΠΟΣ2 ☐
    ΑΤ ☐ ΔΤ ☐ ΟΤ ☐ ΕΤ ☐
    ΧΛ1α ☐ ΧΛ1β ☐ ΧΛ2α ☐ ΧΛ2β ☐

ΕΝΟΤΗΤΑ Ε : ΣΤΟΙΧΕΙΑ ΤΡΩΤΟΤΗΤΑΣ

(Σημειώστε με Χ τις θετικές απαντήσεις στα παρακάτω ερωτήματα)

29. Χωρίς αντισεισμικό κανονισμό ☐
30. Έχει αυξηθεί η σπουδαιότητα λόγω αλλαγής της χρήσης ☐
31. Προηγούμενες σεισμικές επιβαρύνσεις ☐
32. Κακή κατάσταση λόγω ελλιπούς συντήρησης/κακοτεχνιών/καθιζήσεων ☐
33. Κίνδυνος κρούσης με γειτονικά κτίρια ☐
34. Μαλακός όροφος ☐
35. Μη κανονική διάταξη τοιχοπλήρωσης σε κάτοψη ☐
36. Μεγάλο ύψος ☐
37. Μη κανονικότητα καθ' ύψος ☐
38. Οριζόντια μη κανονικότητα ☐
39. Ενδεχόμενο στρέψης ☐
40. Κοντά υποστυλώματα ☐

Σημείωση: Για τυχόν πρόσθετες πληροφορίες παρακαλούμε απευθύνεστε στον ΟΑΣΠ / Τμήμα Αντισεισμικής Τεχνολογίας (e-mail: "**info@oasp.gr**").
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ΟΡΓΑΝΙΣΜΟΣ ΑΝΤΙΣΕΙΣΜΙΚΟΥ ΣΧΕΔΙΑΣΜΟΥ ΚΑΙ ΠΡΟΣΤΑΣΙΑΣ
Ξάνθου 32 15451, Ν. Ψυχικό Τηλ. 210 6728000, 210 6725233 Fax 210 6779561, e-mail info@oasp.gr

Figure 3. Rapid Visual Screening collection form

The collection form of the EPPO RVS procedure is presented in Figure 3. In Section A of the Collection Form, data pertaining to the identity of the investigated building are included.

Section B pertains to technical data of the building, including information on number of storeys, typical floor area and total area, year of construction and latest appendage (if any), as well as information about the availability of blueprints/design data, if the building has been characterized as culturally important, and if any strengthening/repair interventions have ever taken place. The building is also assigned its (usage-dependant) importance according to Greek National Seismic Code (EAK2000), ranging (in increasing importance) from Σ1 to Σ4. Schools are to be considered of Σ3 importance according to EAK2000.

Section C (Γ in Greek, Figure 3) comprises seismological and geotechnical data, such as the seismic hazard zone according to current Greek National Seismic Code (EAK2000), as well as the seismic code according to which the building was designed. Three distinct periods are considered, namely prior to 1995, between 1995 and 2003 and after 2004, corresponding to different versions of the National Seismic Code applied during each period. Also, the soil type classification (A, B, C, D, X or Unknown) according to EAK2000 is to be filled in at the end of the section.

The structural type of the building is to be defined in section D (Δ in Greek). Section E includes data pertaining to factors affecting the seismic vulnerability of the inspected building. A detailed presentation of the RVS procedure is included in D.T3.3.1 deliverable of the REDACt project.

It is evident that the Rapid Visual Screening (RVS) approach can yield substantially more detailed and reliable data compared to the National Census procedure, which is conducted on a larger scale by less experienced personnel (typically with no engineering background). However, RVS data are relatively scarce and challenging to obtain for a significant number of buildings. It is worth noting that in 2023, the Greek Government has announced a nationwide preseismic assessment project for all public buildings, including schools, utilizing the RVS approach as the first of a three-part seismic assessment methodology. Currently, civil engineers at the national level are undergoing training in order to implement this task.

3.2 SCHOOL BUILDINGS DATA IN THE PILOT CASE SITE OF ALEXANDROUPOLI

3.2.1 School buildings data based on the ELSTAT National Census

The first source of information for the Municipality of Alexandroupoli is based on the 2011 National Population-Housing Census, applying appropriate filtering to focus exclusively on school buildings. This procedure results to a total of 64 buildings tagged as schools.

The main building properties, with regard to their seismic performance, that are available in the ELSTAT dataset are presented in Figure 4. It is noted that the majority are reinforced concrete buildings, with height up to 3 storeys. Almost 10% of the schools are old stone masonry buildings, constructed before 1960 (Figure 7).

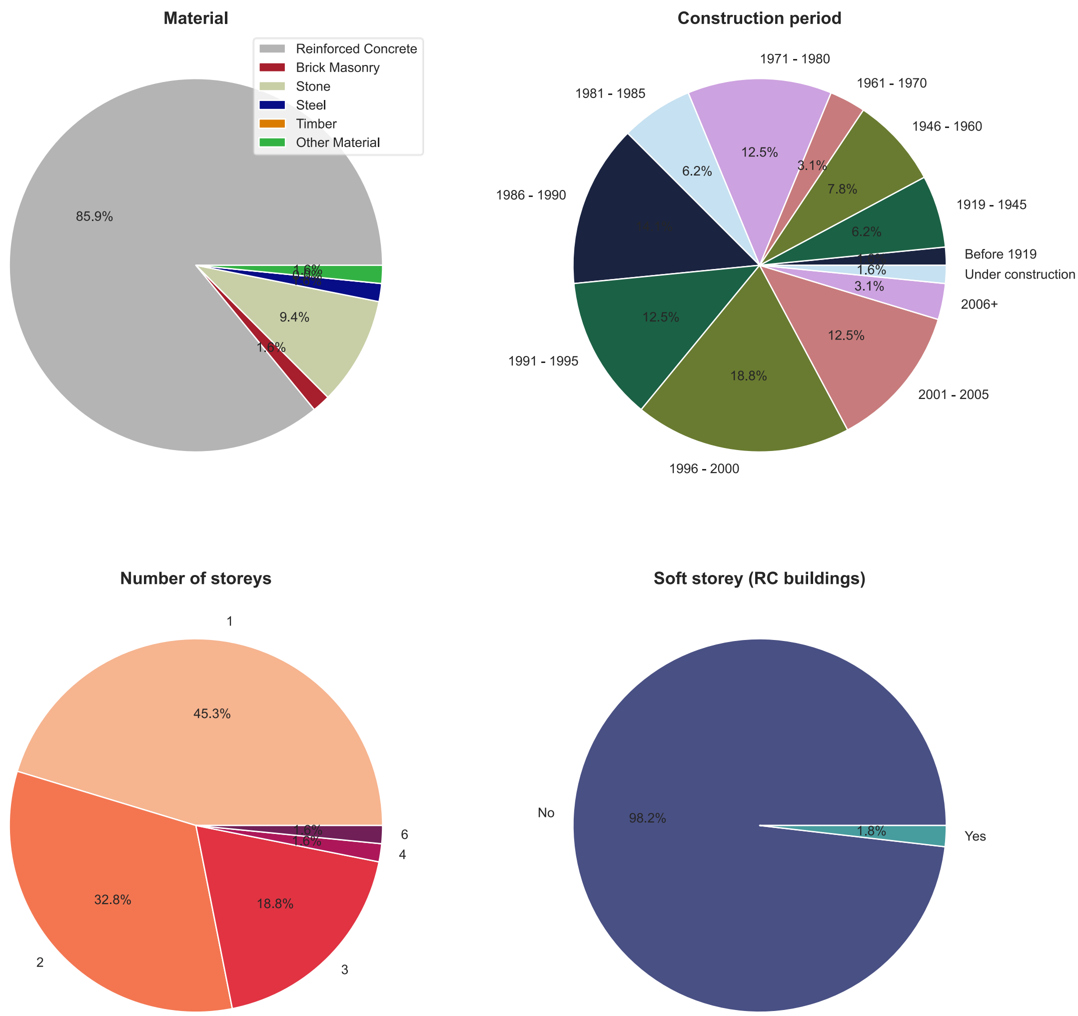

Figure 4. School buildings stock in Alexandroupoli

The spatial distribution of the school buildings in Alexandroupoli is presented in Figure 5; the light blue polygons correspond to the census sectors.

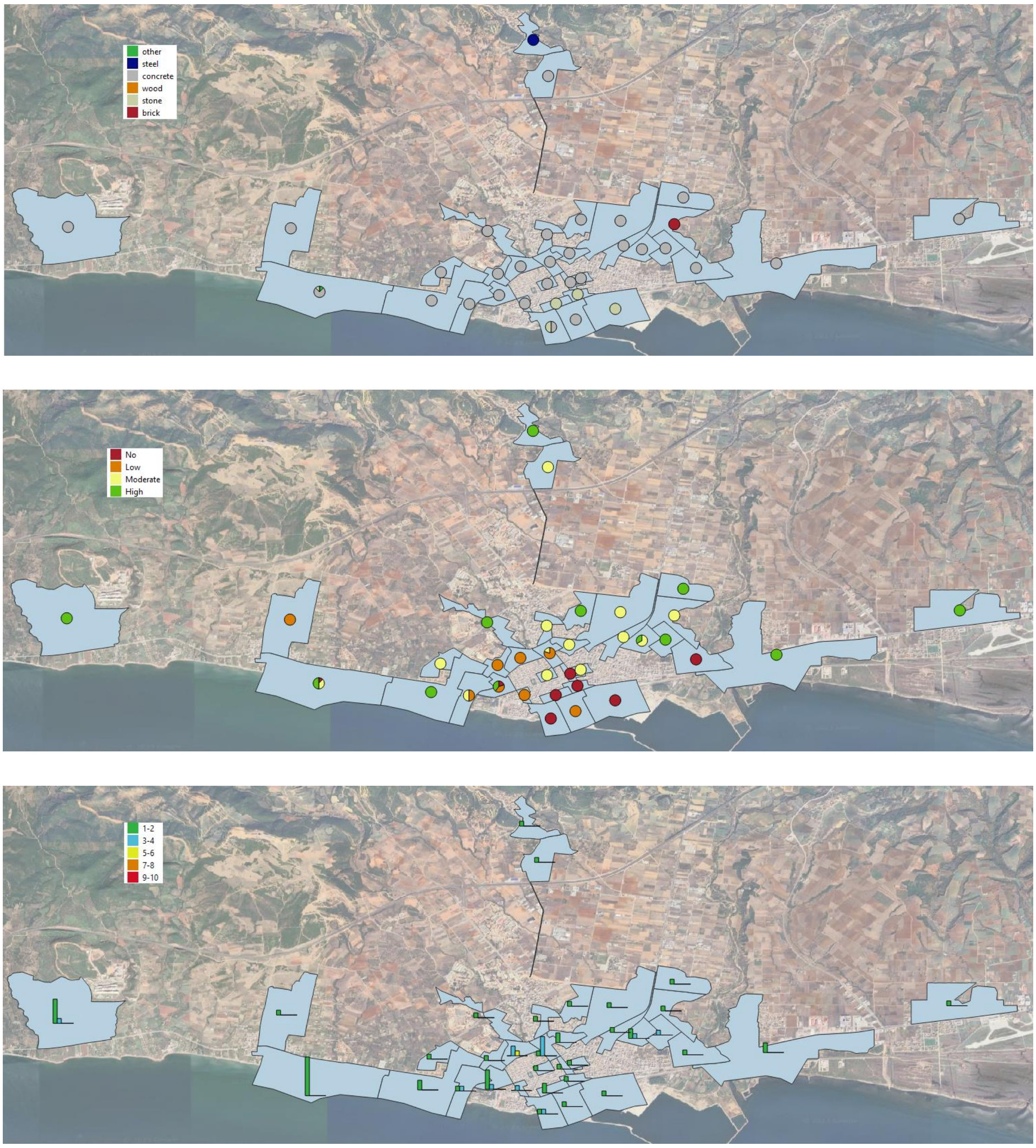

Figure 5. Spatial distribution of the school buildings stock in Alexandroupoli in terms of construction material (top), seismic code level (center) and height (bottom)

A more detailed insight into the characteristics of the building stock of Alexandroupolis can be found in the following figures, where the aforementioned properties are combined in order to present the temporal evolution of the utilized construction materials or the building heights, etc., as well as their interrelations.

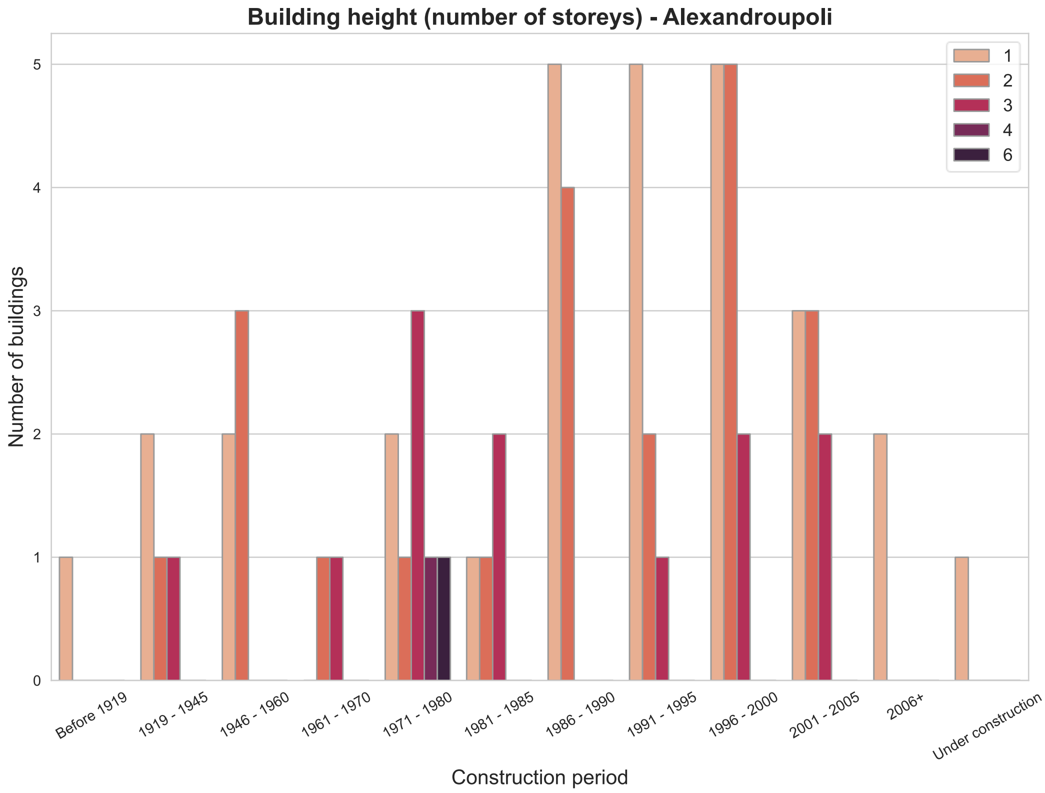

Figure 6. Building height vs construction period of the school buildings in Alexandroupoli

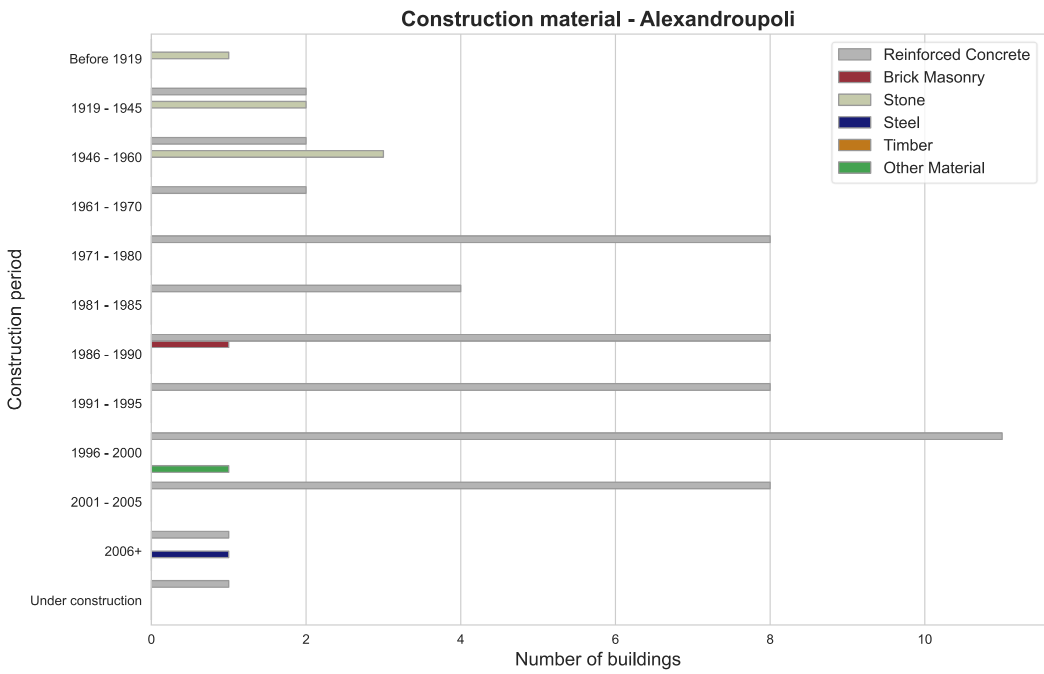

Figure 7. Building material vs construction period of the school buildings in Alexandroupoli

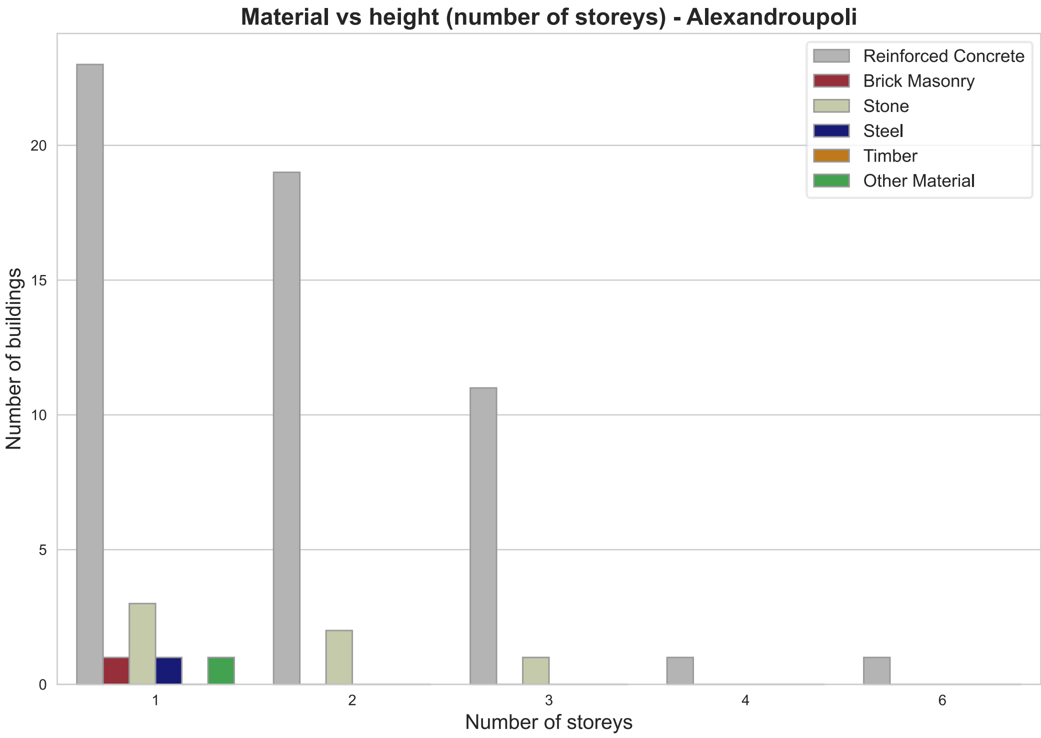

Figure 8. Building height vs construction material of the school buildings in Alexandroupoli

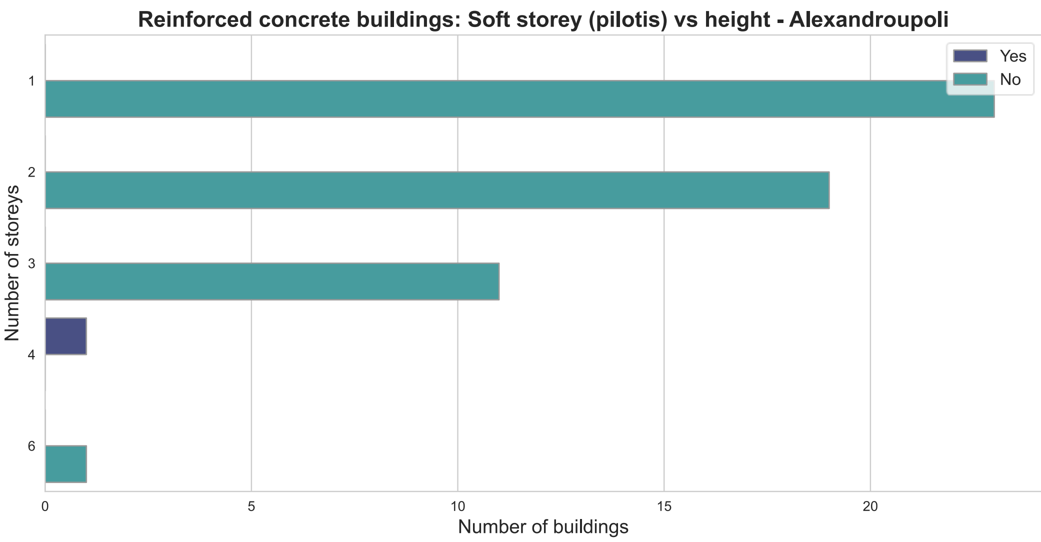

Figure 9. Soft storey vs building height of the school buildings in Alexandroupoli

3.2.2 School buildings data based on the KT.YP. database

In the case of Alexanroupoli, the available data from the Ktiriakes Ypodemes S.A. database refer only to buildings constructed before 1959, i.e. before the first Greek seismic code had been released. The basic structural properties of these buildings are presented in Table 1 and Figure 10.

It is interesting to note that all these buildings are low rise (1-2 storeys) stone masonry buildings.

Table 1. School buildings data in Alexandroupoli based on the KTYP dataset

No.	Material	Construction year	Code Period	Number of Storeys	Soft storey
1	Stone	1952	<1959	2	NO
2	Stone	1928	<1959	2	NO
3	Stone	1920	<1959	3	NO
4	Stone	1955	<1959	1	NO
5	Stone	1958	<1959	2	NO
6	Stone	1958	<1959	2	NO
7	Stone	1958 - 62	<1959	2	NO
8	Stone	1958 - 62	<1959	1	NO
9	Stone	1958 - 62	<1959	1	NO
10	Stone	1958	<1959	1	NO
11	Stone	1952	<1959	2	NO
12	Stone	1886	<1959	2	NO
13	Stone	<1925	<1959	1	NO
14	Stone	< 1958	<1959	1	NO
15	Stone	<1930	<1959	1	NO

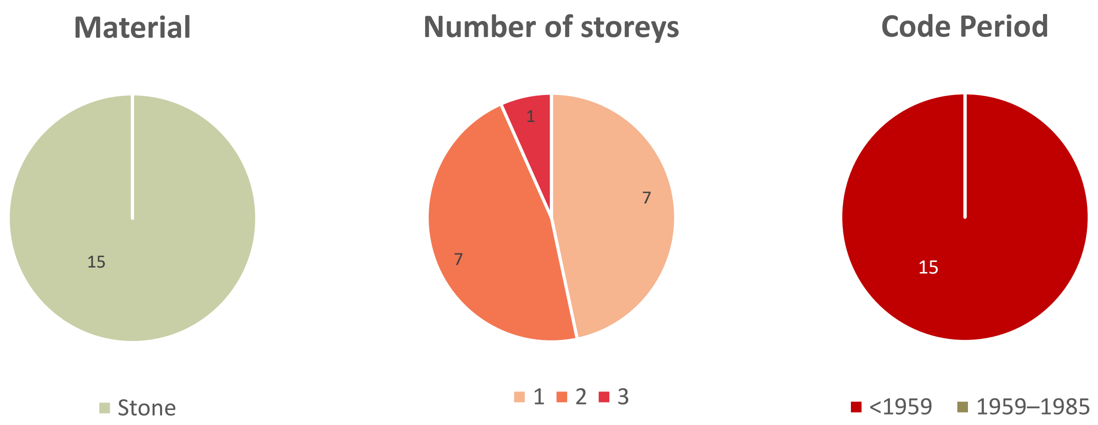

Figure 10. School buildings data in Alexandroupoli based on the KTYP dataset

3.2.3 Typical school buildings in the Municipality of Alexandroupoli

Some examples of school building types in Alexandroupoli are presented in Figure 11.

Figure 11. Various school building types in Alexandroupoli (mainly from the KT.YP. data)

3.3 SCHOOL BUILDINGS DATA IN THE PILOT CASE SITE OF SAMOS CITY

3.3.1 School buildings data based on the ELSTAT National Census

As mentioned earlier, the data from the 2011 National Population-Housing Census for Samos were requested from the Hellenic Statistical Authority but have not been provided yet. Once these data becomeavailable, they will be incorporated within the scope of the current project.

3.3.2 School buildings data based on the KT.YP. database

In the case of Samos city, the available data from the Ktiriakes Ypodemes S.A. database refer only to buildings constructed before 1985, therefore they correspond to buildings designed either according to the first Greek seismic code (released in 1959), or with no seismic code provisions at all (<1959). Figure 12 presents the school complexes in the Samos city that are included in the KT.YP. dataset, or not. It is recalled that each school complex may contain several statically independent buildings, encompassing different activilties such as classrooms, gyms, storage facilities, toilets etc.

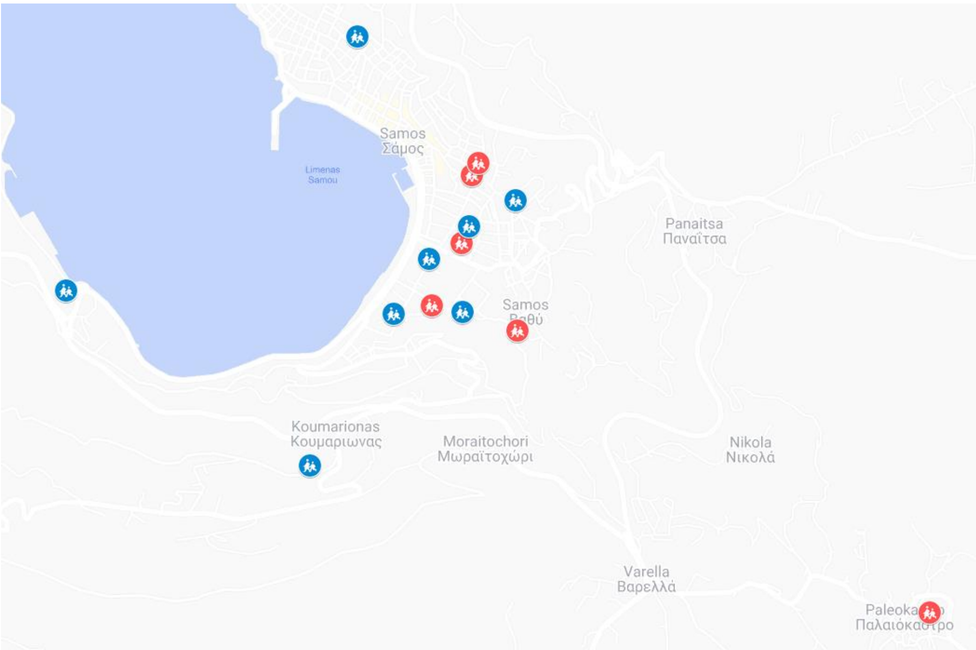

Figure 12. School buildings in Samos/Vathi (red: included in the KT.YP. dataset)

The basic structural properties of these buildings are presented in Figure 13 and Table 2. Similar to the case of Alexandroupoli, the majority of old buildings (constructed before 1959) are made of stone, while after 1959, reinforced concrete became the predominant material. All buildings are low-rise, with either one or two storeys.

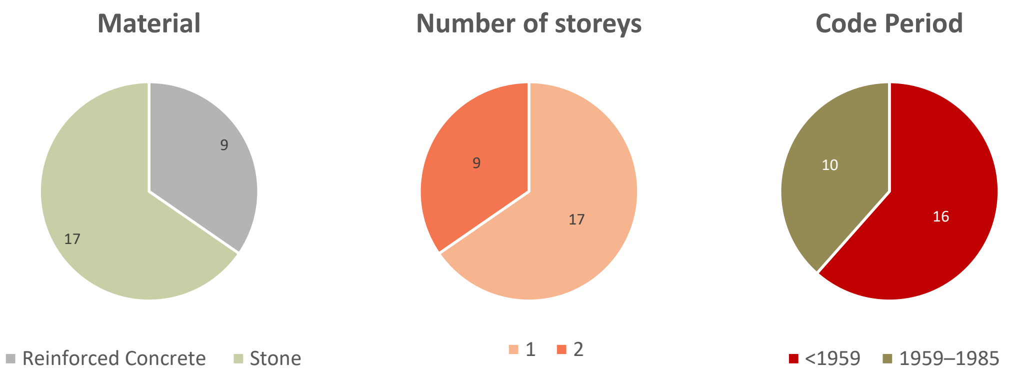

Figure 13. School buildings data in Samos/Vathi based on the KTYP dataset

Table 2. School buildings data in Samos/Vathi based on the KTYP dataset

No.	Material	Constr. year	Code Period	No. of Storeys	Soft storey
1	R/C	1980	1959-1985	1	NO
2	R/C	1980	1959-1985	1	NO
3	Stone	1934	<1959	1	NO
4	Stone	1958	<1959	2	NO
5	Stone	1958	<1959	2	NO
6	Stone	1934	<1959	1	NO
7	Stone	1934	<1959	2	NO
8	Stone	1934	<1959	2	NO
9	R/C	1985	1959-1985	2	NO
10	R/C	1970	1959-1985	1	NO
11	R/C	1970	1959-1985	2	NO
12	R/C	1970	1959-1985	1	NO
13	Stone	1934	<1959	1	NO
14	R/C	1970	1959-1985	1	NO
15	Stone	1860	<1959	2	NO
16	Stone	1958	<1959	1	NO
17	Stone	1901	<1959	2	NO
18	Stone	1930	<1959	1	NO
19	Stone	1975	1959-1985	2	NO
20	R/C	1970	1959-1985	1	NO
21	R/C	1985	1959-1985	1	NO
22	Stone	1958	<1959	1	NO
23	Stone	1902	<1959	1	NO
24	Stone	1938	<1959	1	NO
25	Stone	1958	<1959	1	NO
26	Stone	1951	<1959	1	NO

3.3.3 Typical school buildings in Samos

Some examples of the school buildings in the city of Samos are presented in Figure 14.

Figure 14. Various school building types in Samos/Vathi (mainly from the KT.YP. data)

3.4 SCHOOL BUILDINGS DATA IN NORTHERN GREECE

Due to the relatively small number of school buildings in the pilot cities of Alexandroupoli and Samos, a decision was made to explore additional locations to obtain a clearer understanding of the most common typologies of school buildings in Greece. These locations included:

- The Region of Eastern Macedonia and Thrace, falling within the eligible area of the current project as part of the Greece-Türkiye CBA
- The Municipality of Thessaloniki, chosen as the largest city in Northern Greece, to examine a substantial number of school buildings.

3.4.1 School buildings in the Region of Eastern Macedonia and Thrace

3.4.1.1 School buildings in the Municipality of Komotini

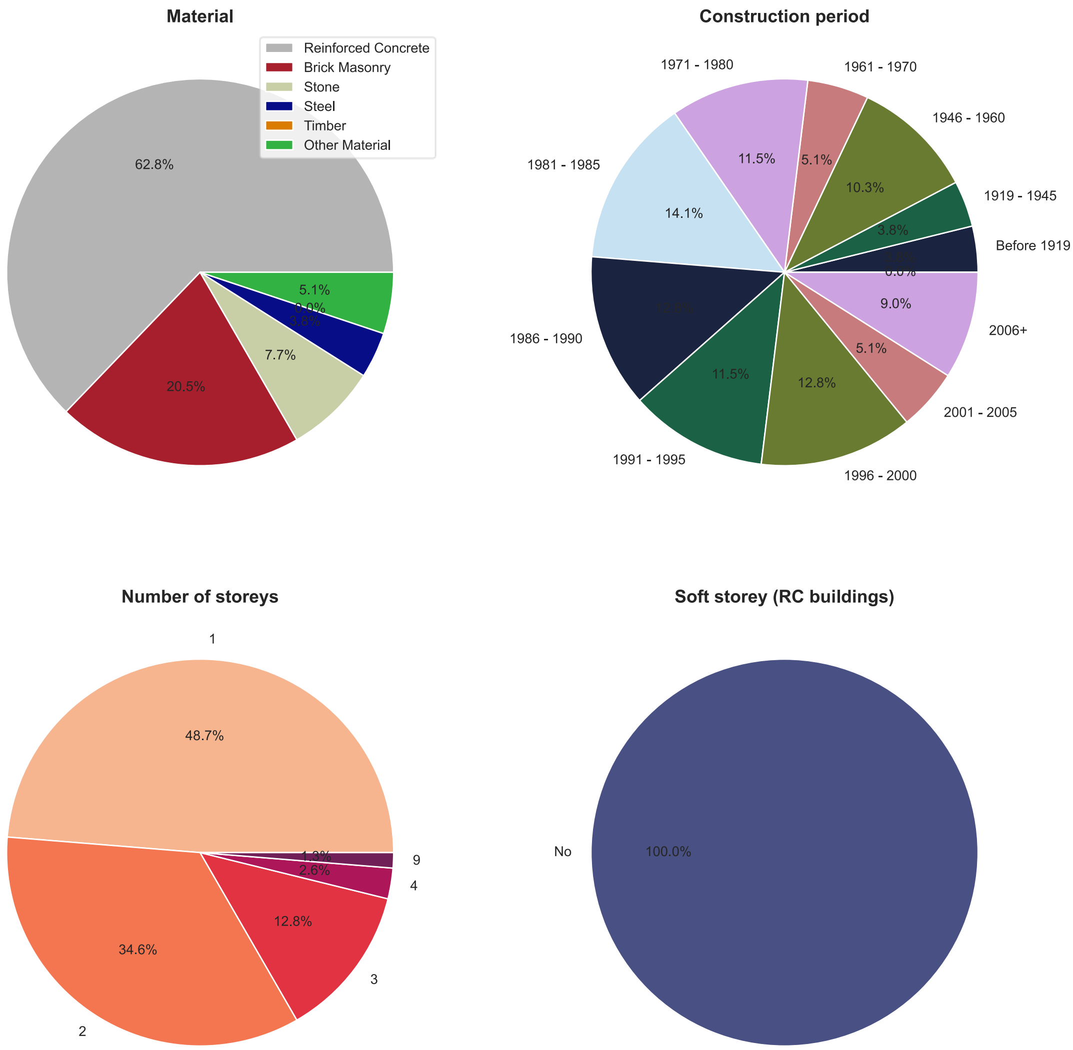

Figure 15. School buildings stock in Komotini

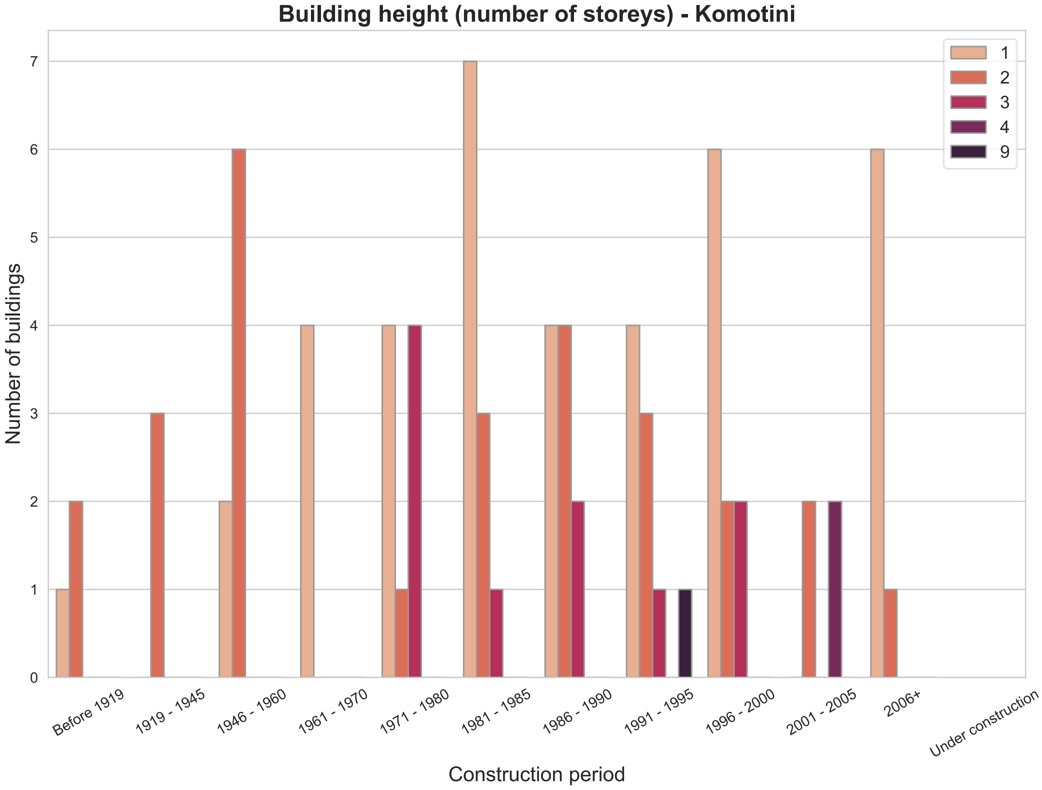

Figure 16. Building height vs construction period of the school buildings in Komotini

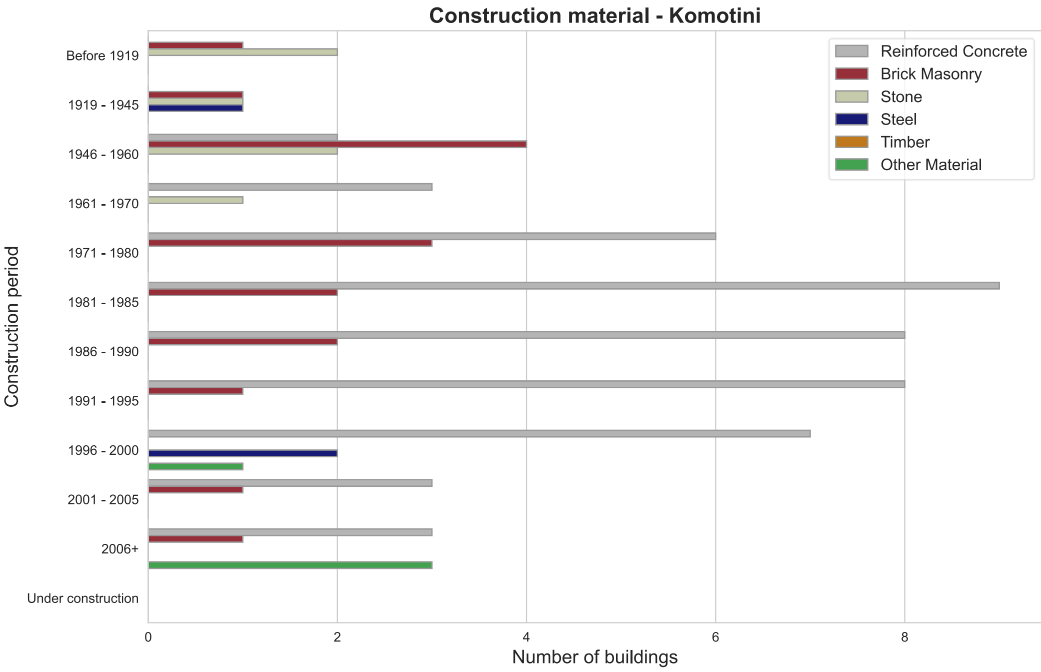

Figure 17. Building material vs construction period of the school buildings in Komotini

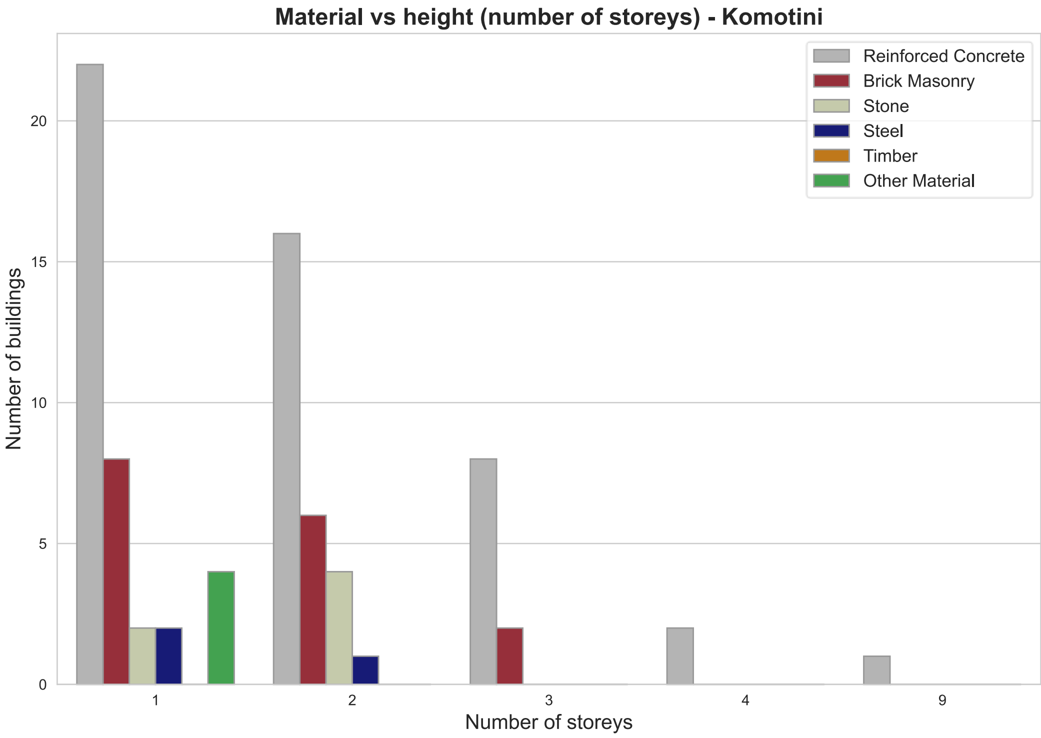

Figure 18. Building height vs construction material of the school buildings in Komotini

The majority of the school buildings in Komotini are low-rise (≤3 storeys), mainly from reinforced concrete (≈63%), while there is a significant number of brick masonry buildings (≈20%).

3.4.1.2 School buildings in the Municipality of Xanthi

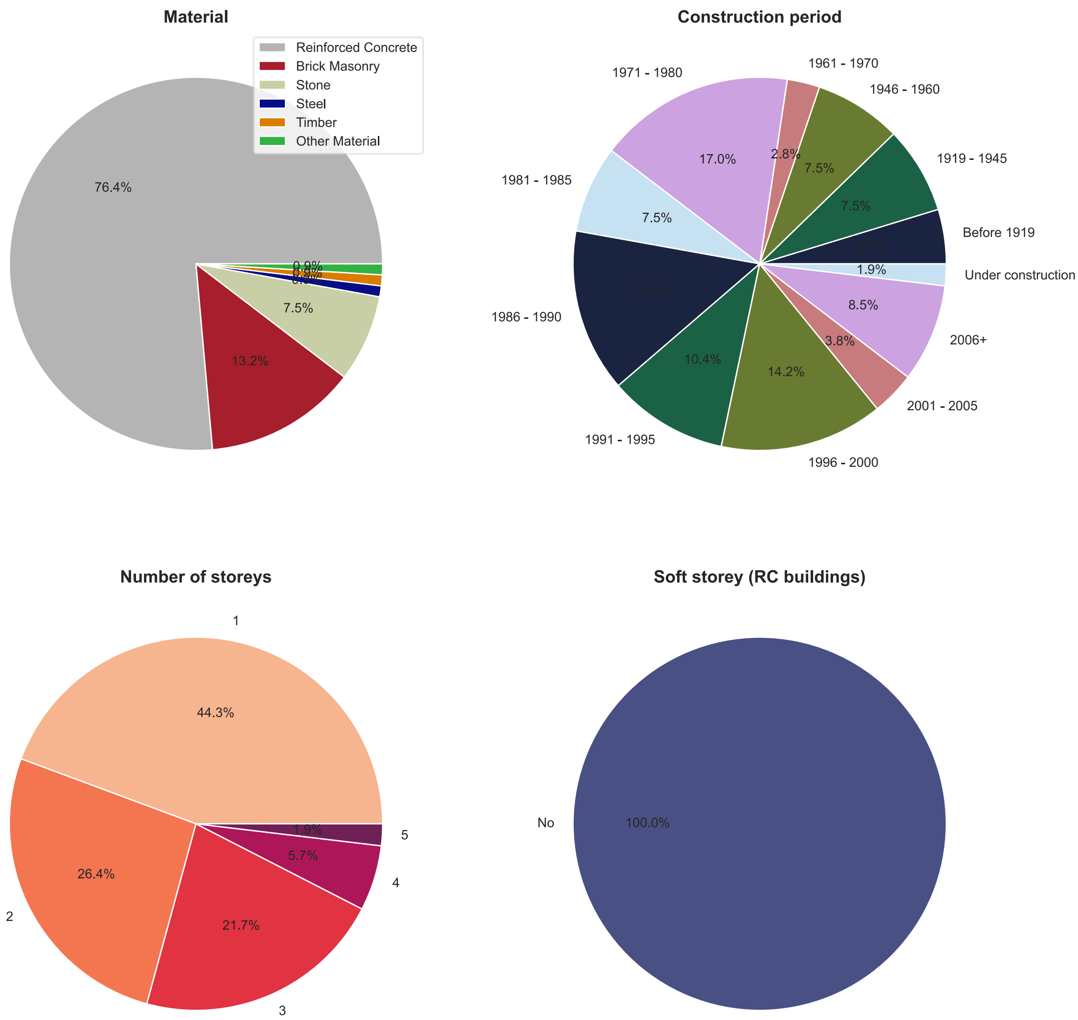

Figure 19. School buildings stock in Xanthi

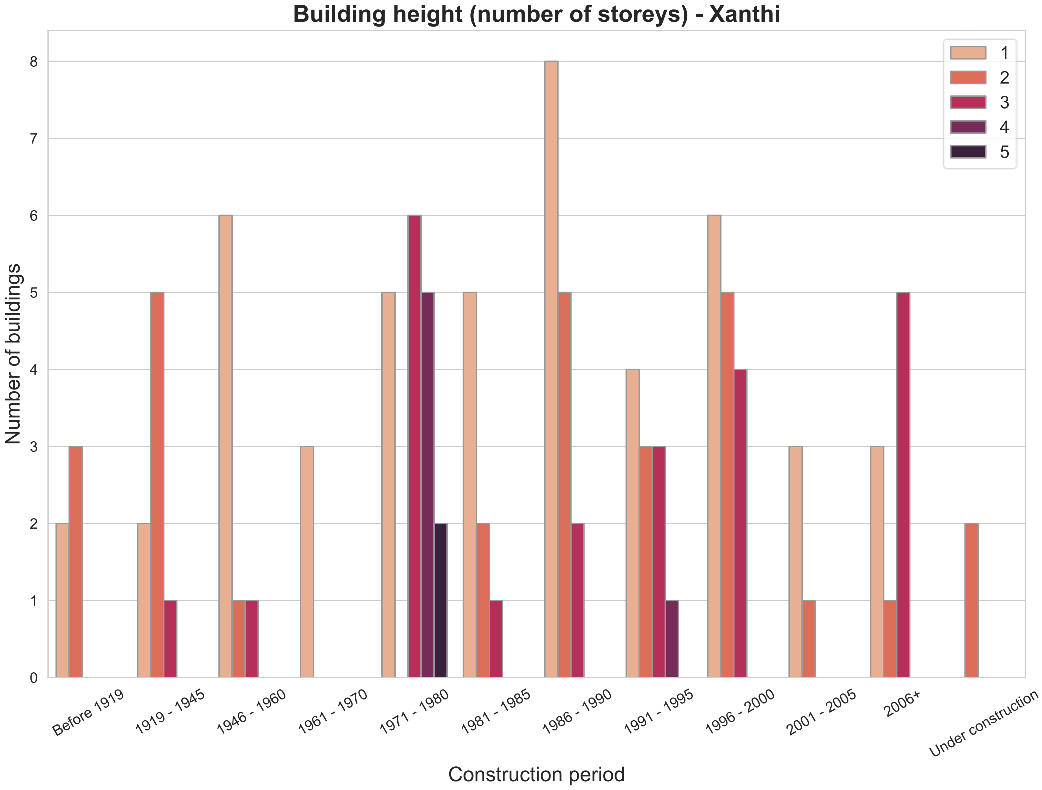

Figure 20. Building height vs construction period of the school buildings in Xanthi

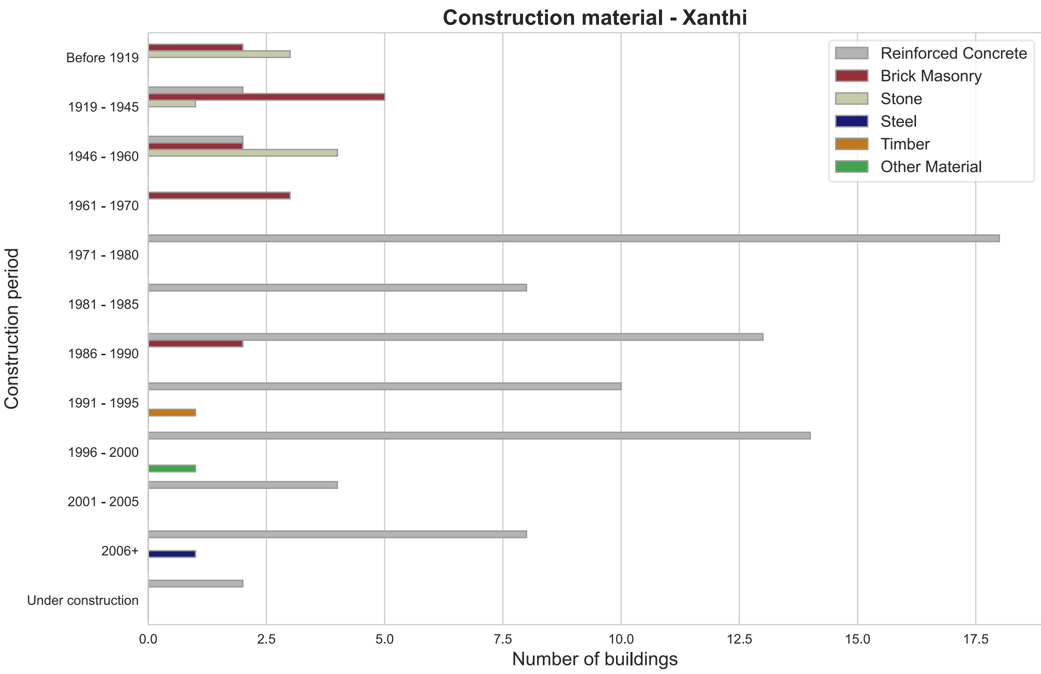

Figure 21. Building material vs construction period of the school buildings in Xanthi

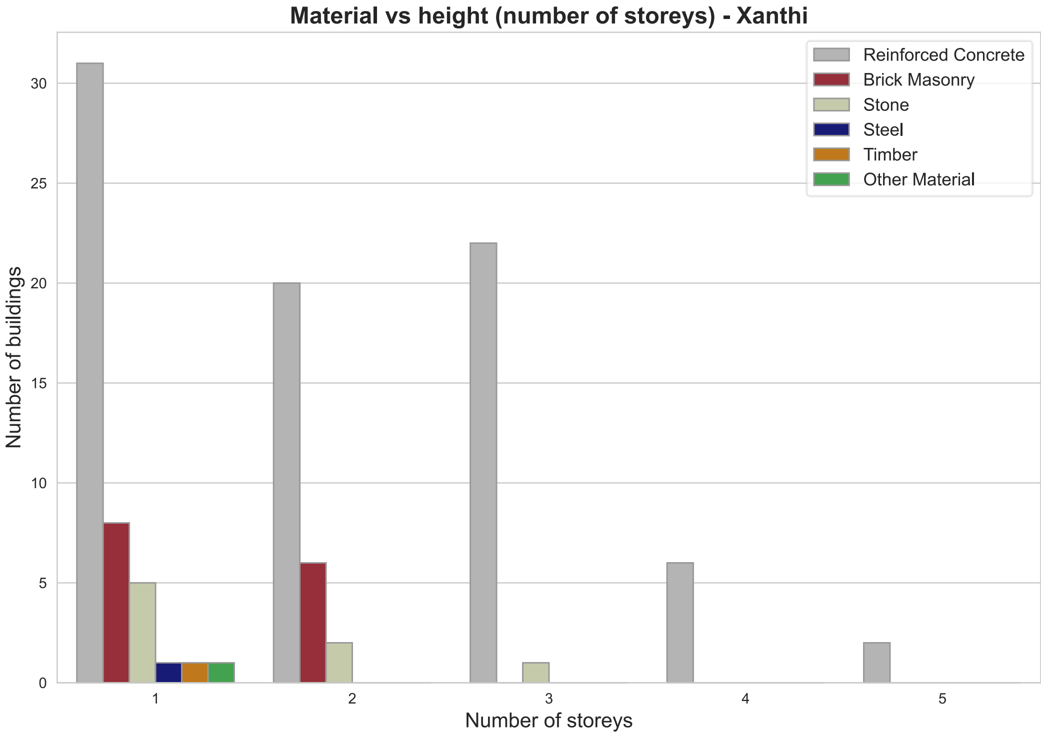

Figure 22. Building height vs construction material of the school buildings in Xanthi

The majority of the school buildings in Xanthi are low-rise (≤3 storeys); some higher (4—5 storeys) buildings correspond to the Democritus University of Thrace. The most dominant material is reinforced concrete (≈76%), while there is a significant number (≈20%) of brick (≈13%) and stone (≈7%) older masonry buildings.

3.4.1.3 School buildings in the Municipality of Kavala

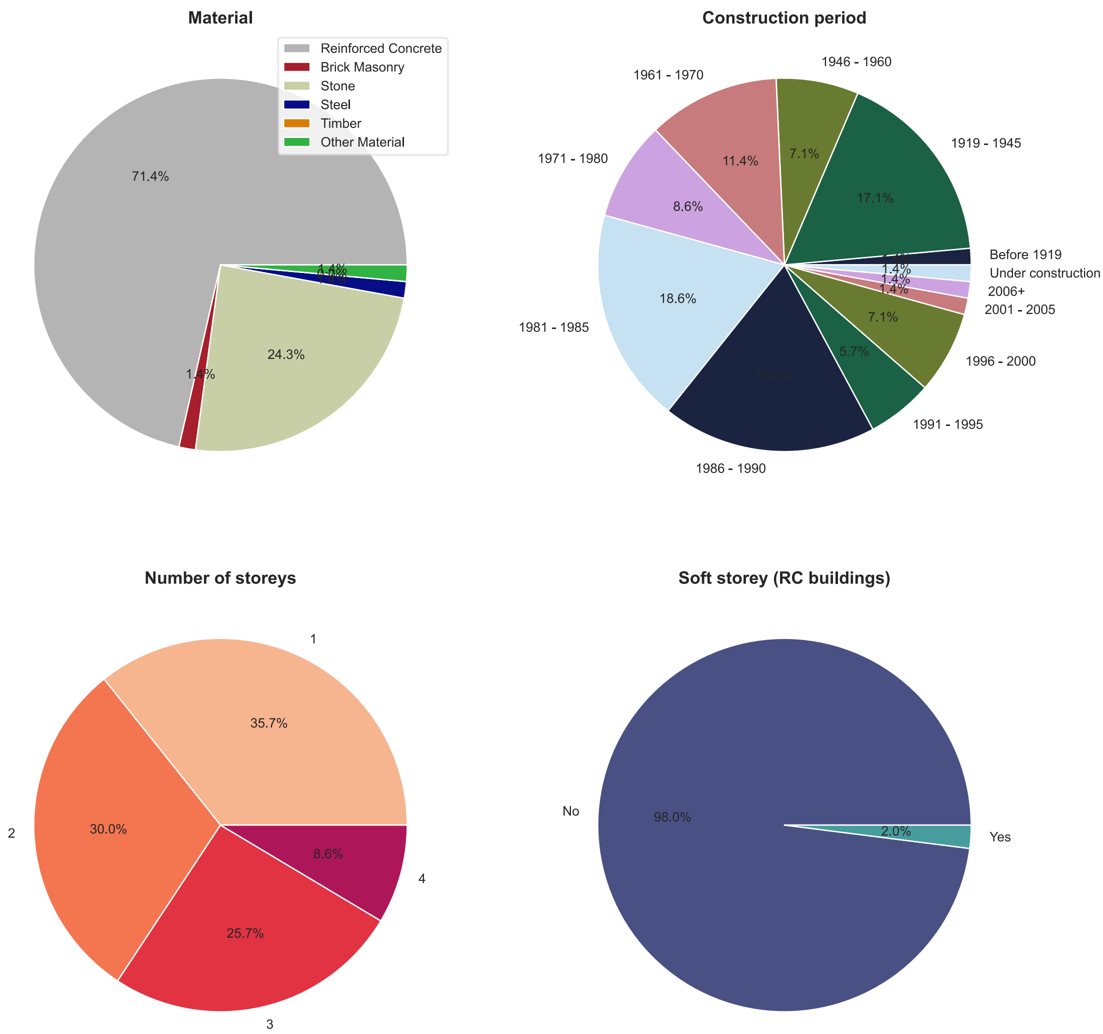

Figure 23. School buildings stock in Kavala

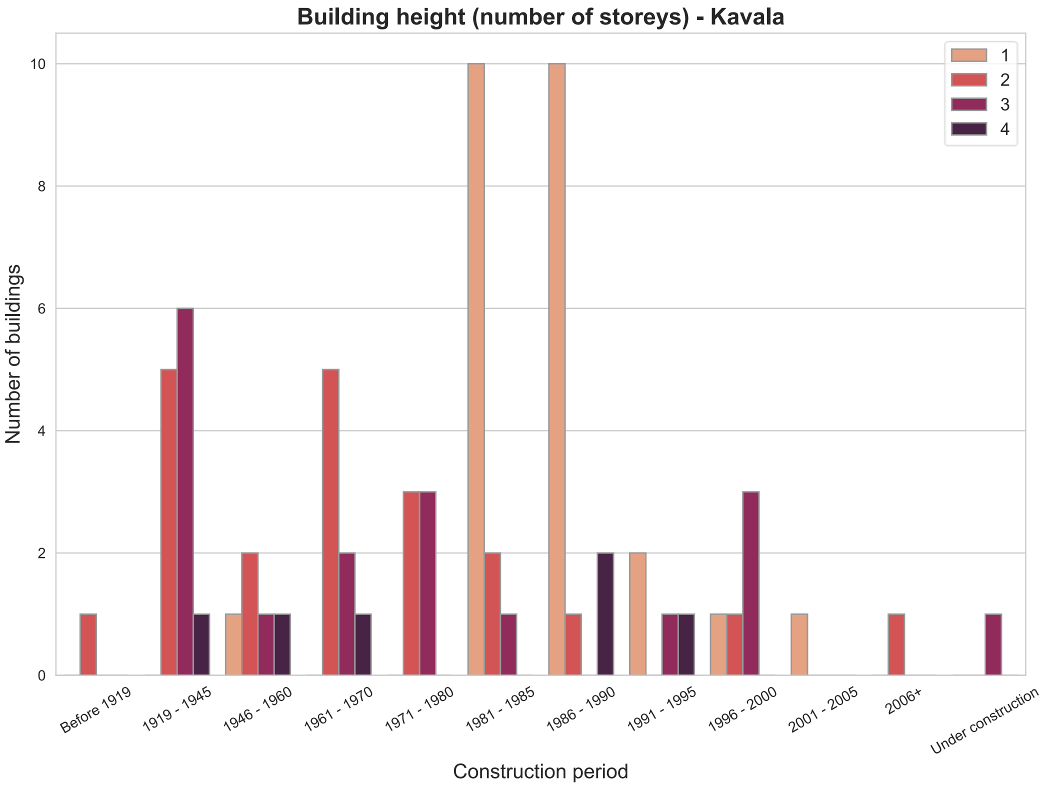

Figure 24. Building height vs construction period of the school buildings in Kavala

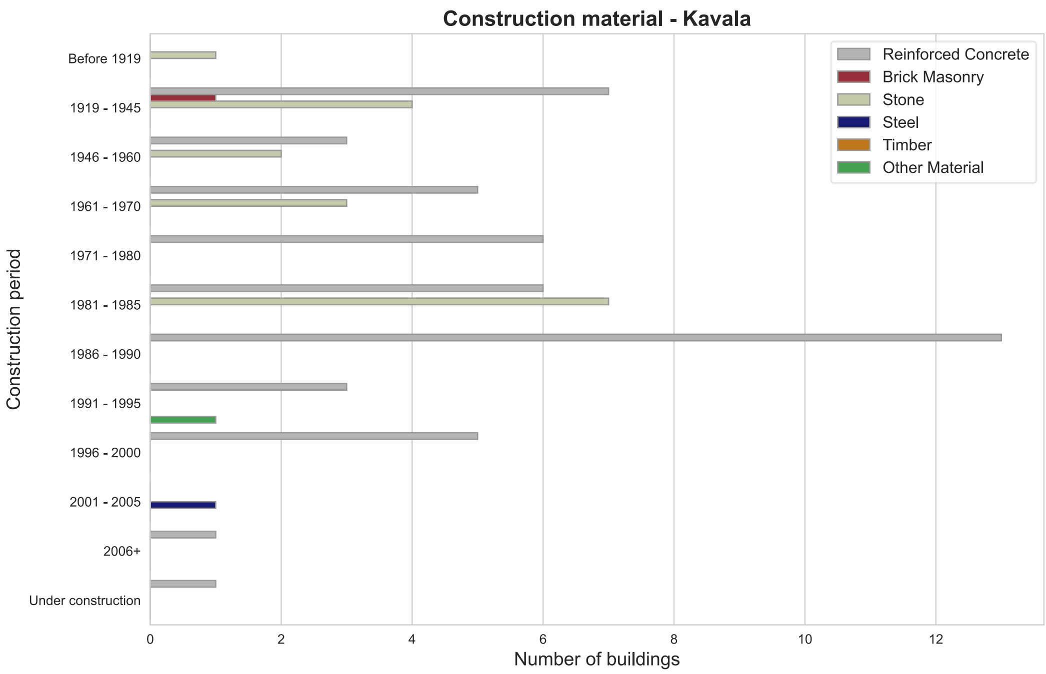

Figure 25. Building material vs construction period of the school buildings in Kavala

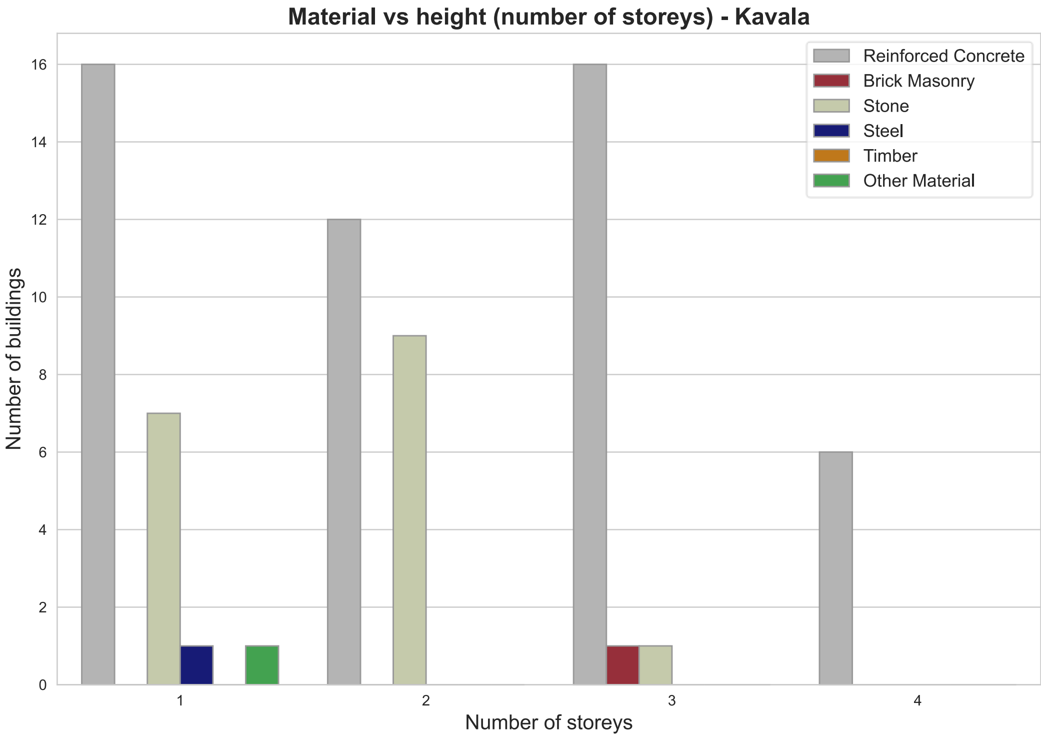

Figure 26. Building height vs construction material of the school buildings in Kavala

The majority of the school buildings in Kavala are low-rise (≤3 storeys), mainly from reinforced concrete (≈71%), while there is a significant number of older stone masonry buildings (≈24%).

3.4.1.4 School buildings in the Municipality of Drama

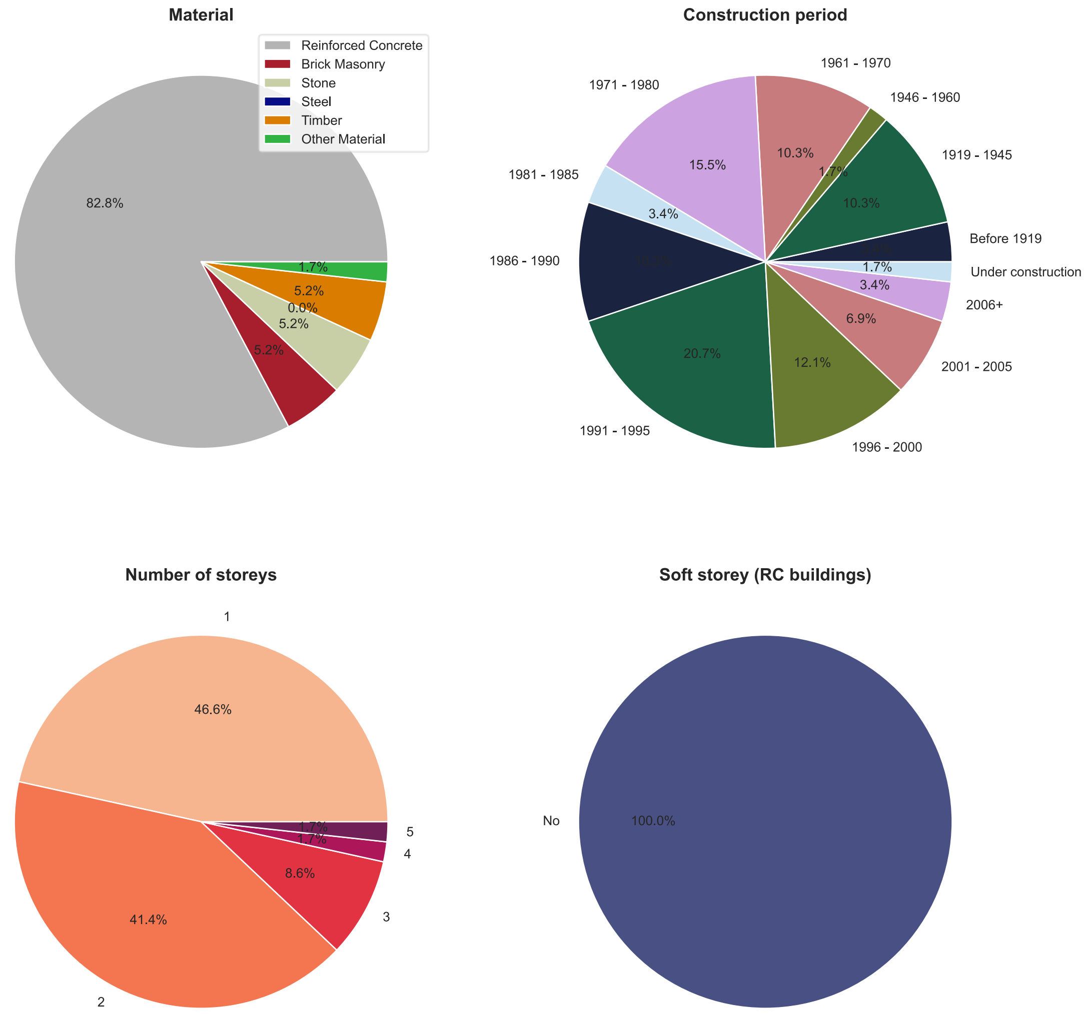

Figure 27. School buildings stock in Drama

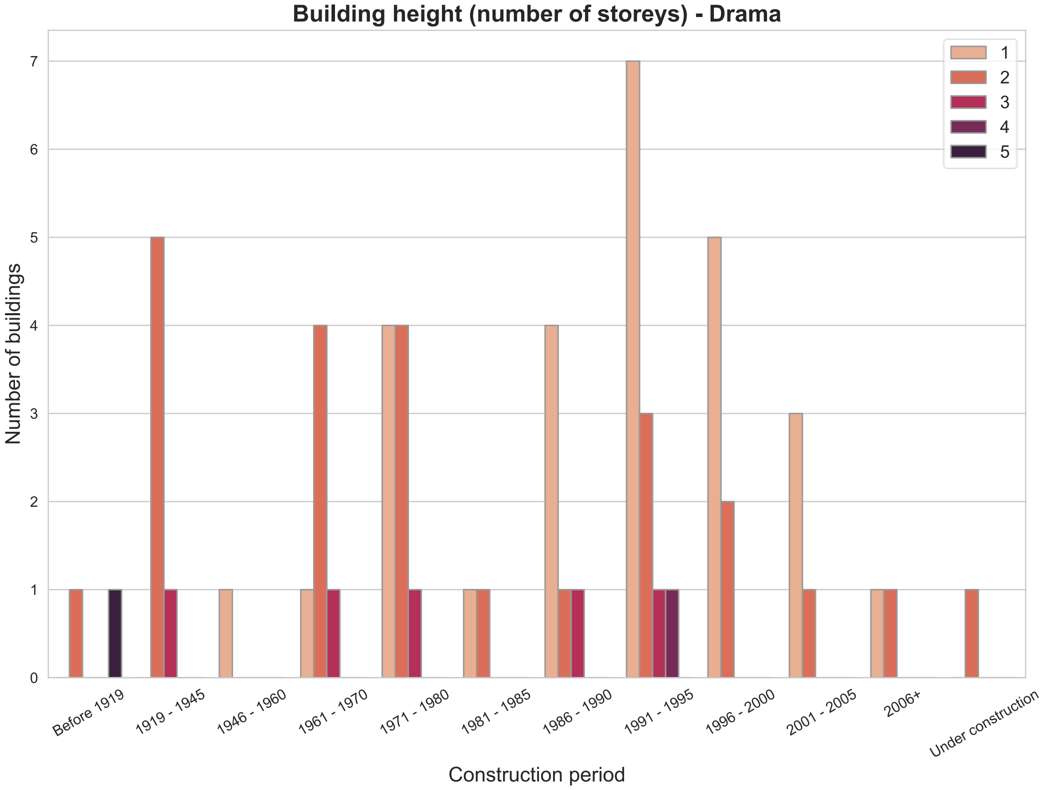

Figure 28. Building height vs construction period of the school buildings in Drama

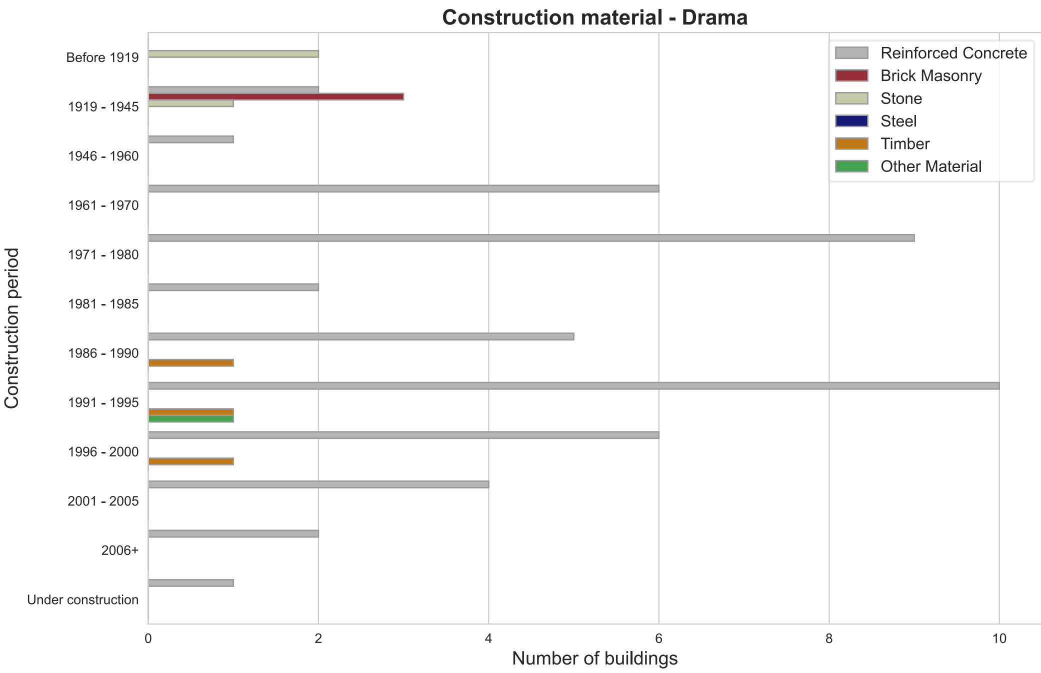

Figure 29. Building material vs construction period of the school buildings in Drama

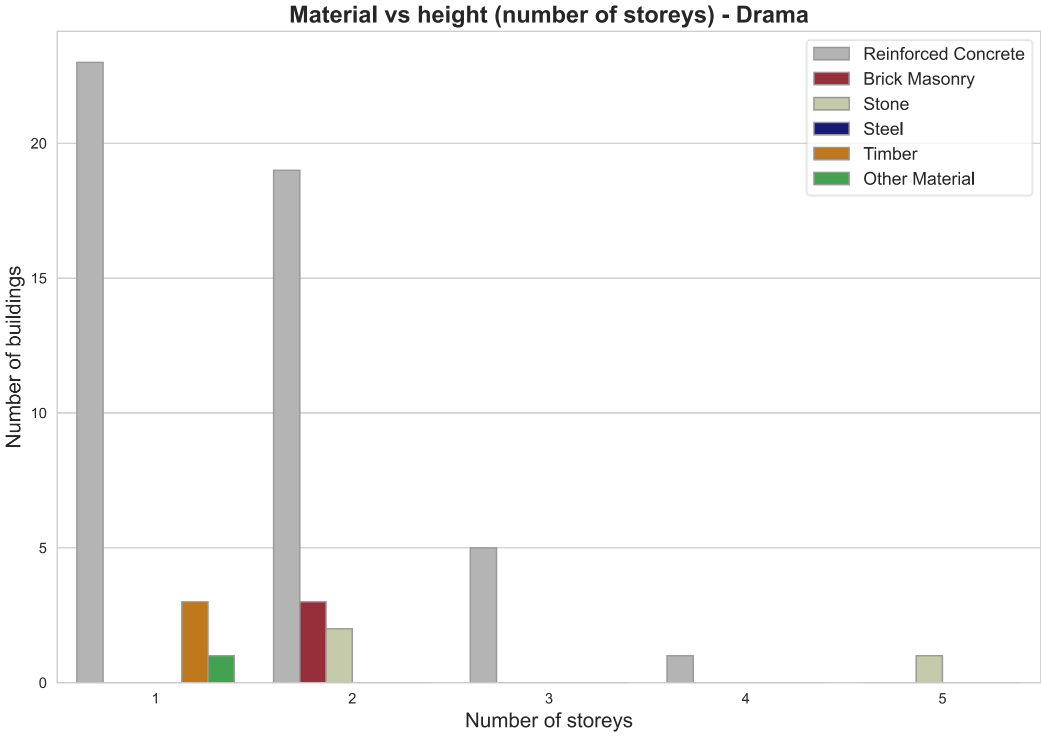

Figure 30. Building height vs construction material of the school buildings in Drama

The majority of the school buildings in Drama are low-rise (≤3 storeys), mainly from reinforced concrete (≈83%), while a lower percentage of nearly 15% is almost evenly distributed between brick masonry, stone masonry and timber buildings.

3.4.2 School buildings in the Municipality of Thessaloniki

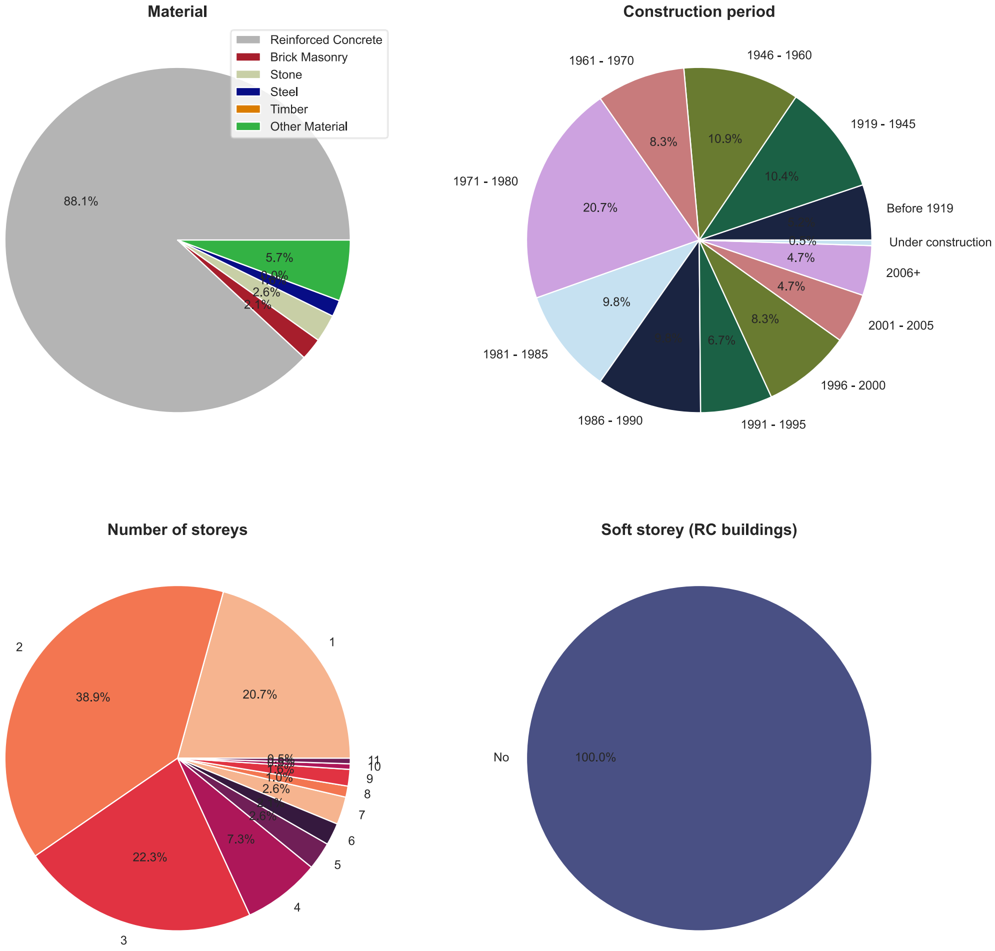

Figure 31. School buildings stock in Thessaloniki

Figure 32. Building height vs construction period of the school buildings in Thessaloniki

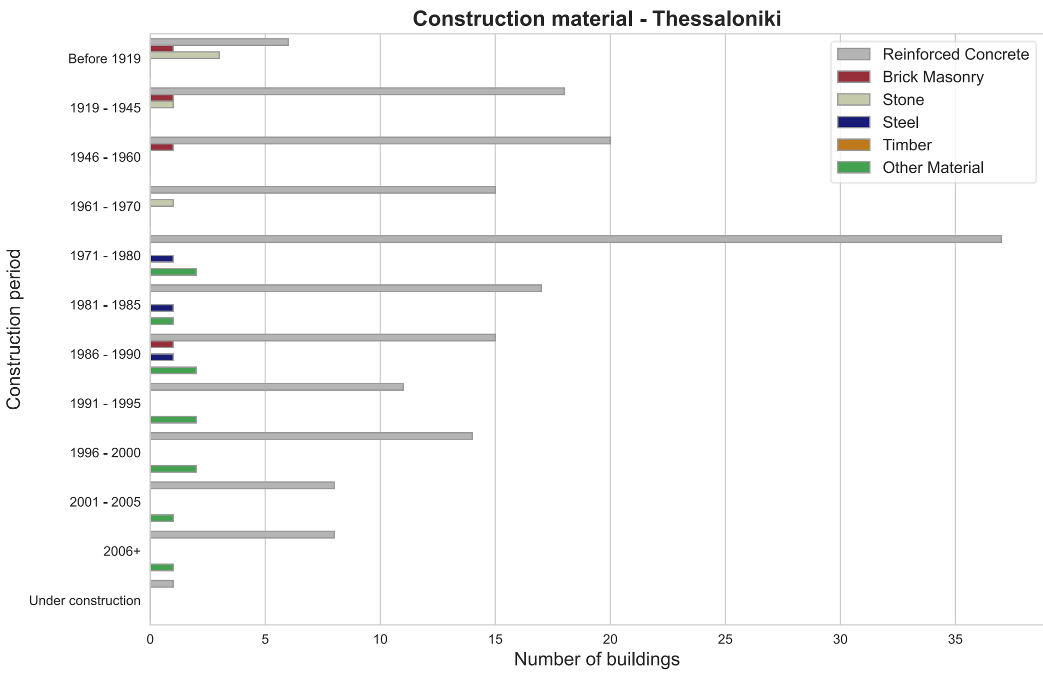

Figure 33. Building material vs construction period of the school buildings in Thessaloniki

Figure 34. Building height vs construction material of the school buildings in Thessaloniki

The majority of school buildings in Thessaloniki are low-rise, with nearly 80% having three or fewer storeys. Some high-rise buildings are associated with the universities (Aristotle University of Thessaloniki and University of Macedonia). The predominant material used is reinforced concrete, constituting approximately 88% of the buildings. Additionally, there is a notable number (approximately 6%) of buildings labeled as "other material," typically corresponding to precast structures.

3.5 DISCUSSION ON THE SCHOOL BUILDING STOCK IN GREECE

Having examined a dataset comprising several hundred records from two sources, mainly in the Greece-Türkiye Cross Border Area, we can draw some conclusions regarding the composition of the Greek schoaol building stock.

- The majority of the Greek school buildings in Greece are low-rise, typically consisting of 1 to 3 storeys.
- Reinforced concrete is the predominant material in constructions dating from the second half of the 20^{th} century and beyond
- A considerable number of older school buildings are constructed with stone masonry or brick masonry and are still in use for educational purposes
- In some areas, there is a smaller number of school buildings made from other materials, such as timber or precast structures

4 STRUCTURAL PROPERTIES OF SCHOOL BUILDINGS IN TÜRKIYE

4.1 GENERAL/INTRODUCTION

A 2-stage method was applied in the selection of pilot schools in the EReS project. In the first stage, the available data were harmonized with the help of GIS techniques and prepared within the framework of the model presented in Figure 35.

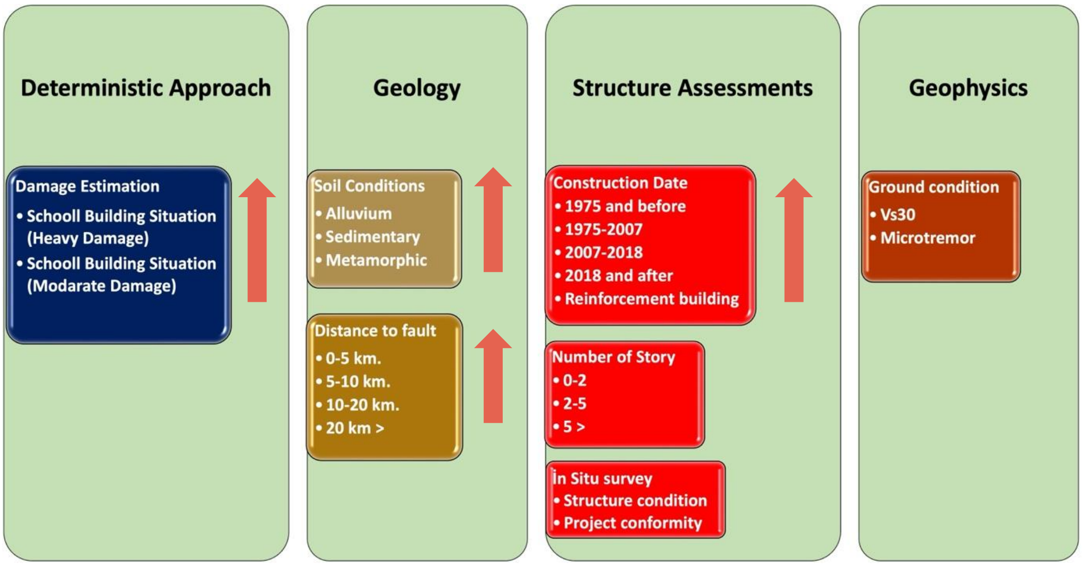

Figure 35. Model used in the selection of pilot schools (In this model, the risk factor for earthquakes is shown in the direction of the arrow from low to high).

4.2 AVAILABLE DATASETS

Numerically prepared school distributions, a total of 458 schools in Çanakkale, which was selected as the pilot province of the project, and a total of 2605 schools in Izmir were analyzed as shown in the Figure 36

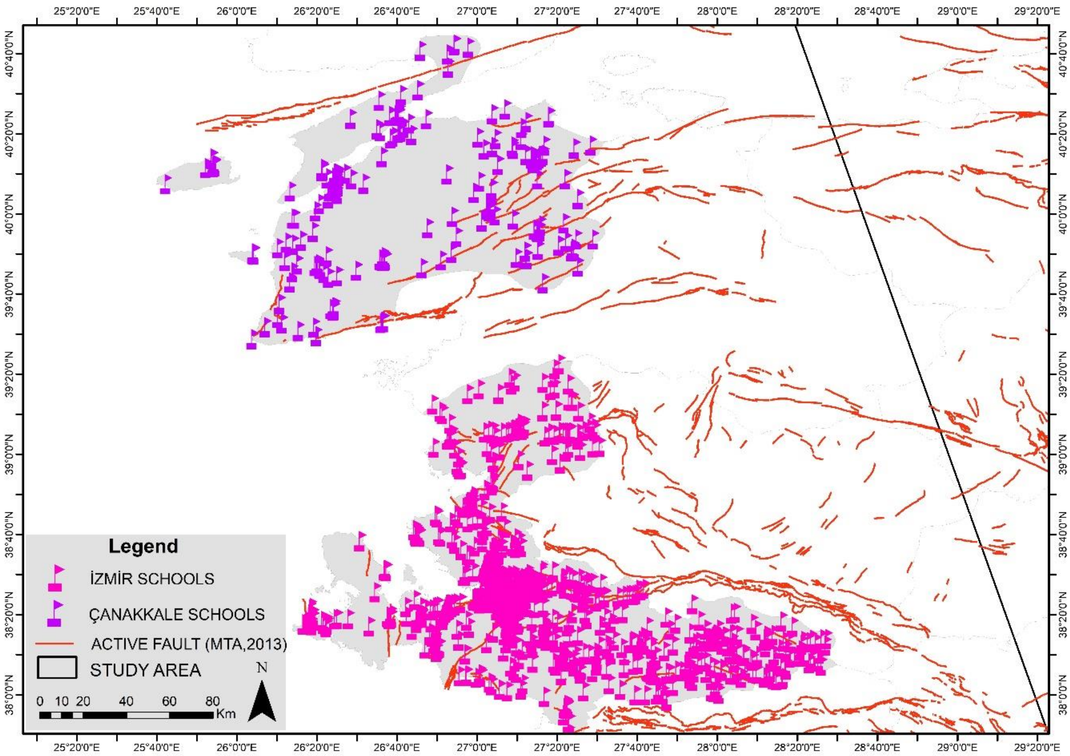

Figure 36. Distribution of schools in pilot provinces selected in the EReS project.

The current geological and fault proximity of the school buildings have been also studied and evaluated in the GIS environment, and 9 schools in Çanakkale and 13 schools in Izmir were determined according to the preliminary evaluation results, on 3 different ground condtion for each province. (Table 3, Figure 37, Figure 38, Figure 39 and Figure 40**Error! Reference source not found.**).

Table 3. School buildings data based on the geologic condition in the pilot sites.

Name of School	District	Soil/Rock Type
Çanakkale Province First Stage Selected Schools		
Mehmet Akif Ersoy Mesleki ve Teknik Anadolu Lisesi	Gelibolu	Alluvion
Ecebey Mesleki Ve Teknik Anadolu Lisesi	Gelibolu	Alluvion
Armatör Yakup Aksoy Anadolu Lisesi	Gelibolu	Metamorphic
İçdaş - Çib Mesleki Ve Teknik Anadolu Lisesi	Lapseki	Metamorphic

Lapseki Anadolu İmam Hatip Lisesi	Lapseki	Alluvion
Hüseyin Akif Terzioğlu Anadolu Lisesi	Lapseki	Alluvion
Çanakkale İbrahim Bodur Anadolu Lisesi	Center	Alluvion
Cevatpaşa Ortaokulu	Center	Sedimantary
Şemsettin Fatma Çamoğlu Ortaokulu	Center	Alluvion
İzmir Province First Stage Selected Schools		
Çınarlı Mesleki ve Teknik Anadolu Lisesi	Konak	Alluvion
Bornova Mesleki ve Teknik Anadolu Lisesi	Bornova	Alluvion
Güzelbahçe 60. yıl Anadolu Lisesi	Güzelbahçe	Alluvion
Piyale Ortaokulu		Alluvion
Ahmet Hakkı Balcıoğlu Mesleki ve Teknik Anadolu Lisesi	Balçova	Sedimantary
Arkas Mesleki ve Teknik Anadolu Lisesi	Narlıdere	Sedimantary
Dokuz Eylül Anadolu Lisesi	Konak	Sedimantary
85. Yıl Anadolu Lisesi	Buca	Sedimantary
80. yıl Gazi Ortaokulu	Urla	Sedimantary
Ali Osman Konakçı Mesleki ve Teknik Anadolu Lisesi	Bayraklı	Volcanic
Teğmen Ali Rıza Akıncı Anadolu Lisesi	Çiğli	Volcanic
Vali Vecdi Gönül Anadolu Lisesi		Volcanic
Beştepeler Mesleki ve Teknik Anadolu Lisesi	Konak	Volcanic

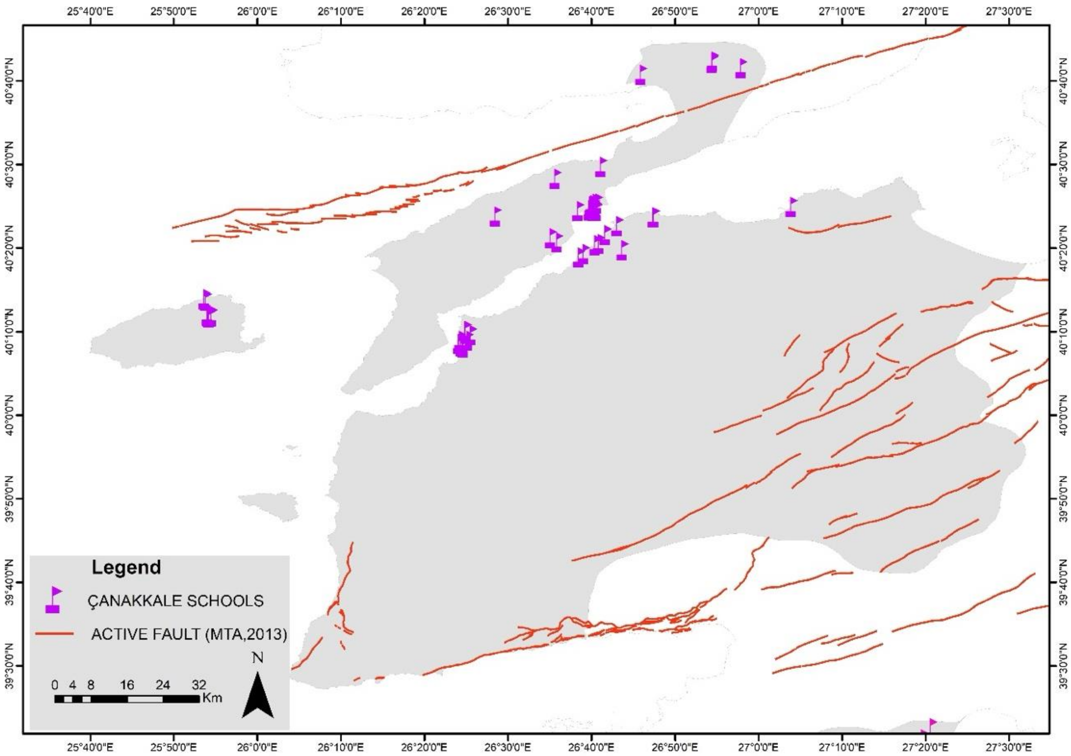

Figure 37. Distribution of schools in pilot Çanakkale province with proximity of existing active fault lines.

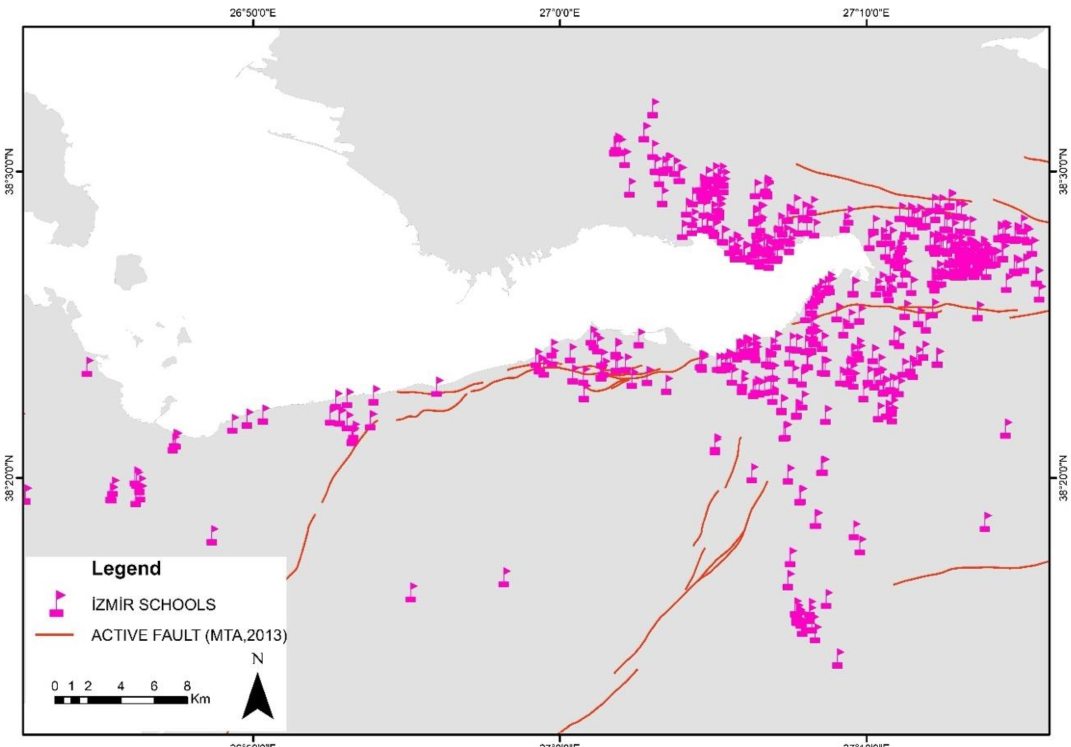

Figure 38. Distribution of schools in pilot İzmir province with proximity of existing active fault lines.

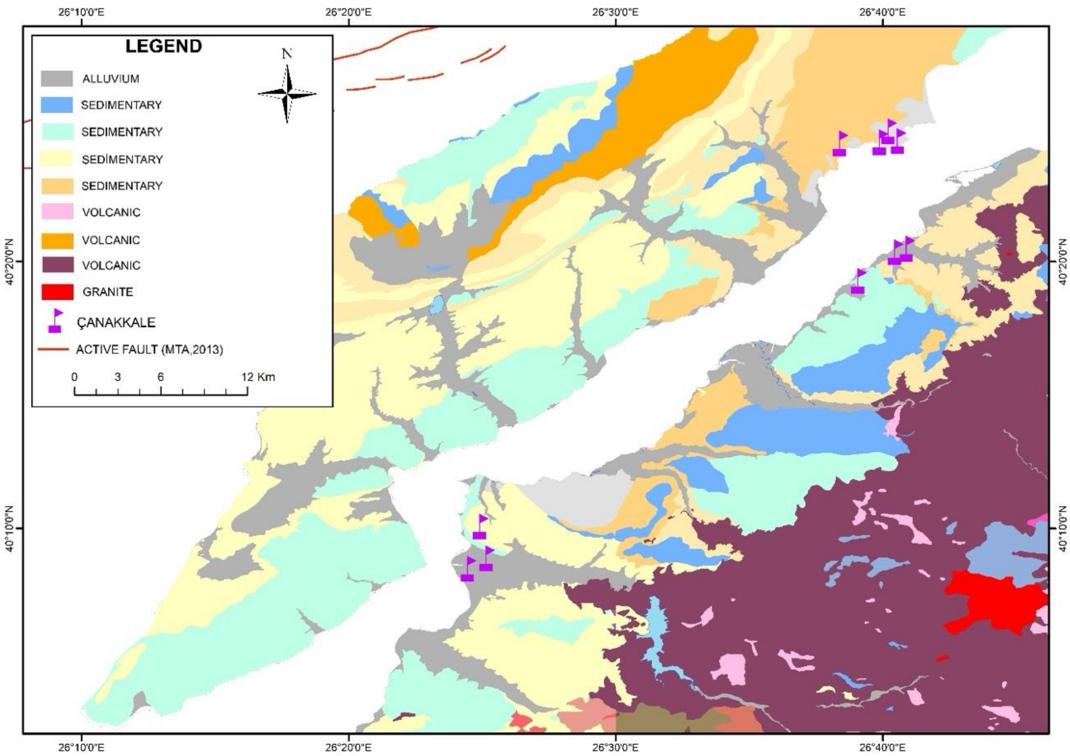

Figure 39. Distribution of school buildings in pilot Çanakkale province with surface geology condition.

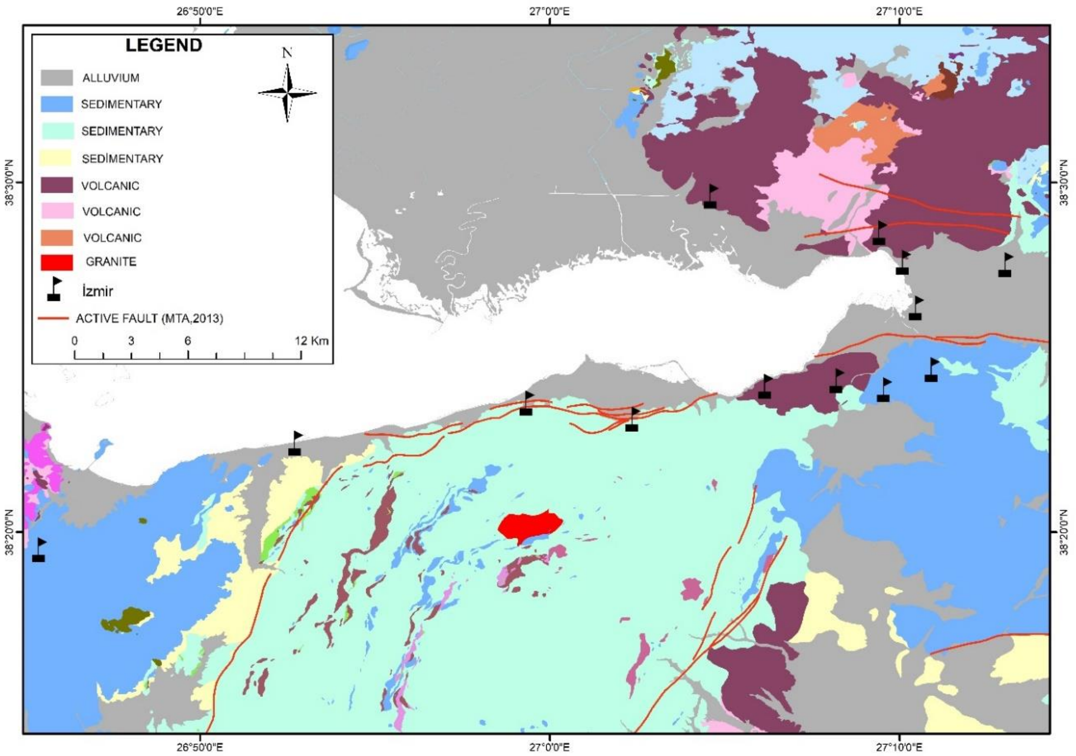

Figure 40. Distribution of school buildings in pilot İzmir province with surface geology condition.

After these analyses, the characteristics of the selected schools (construction material, year of construction, number of floors, number of current students) were collected and added to the database. Within the framework of the model, a field work has been planned to be carried out in December for on-site observation of the schools in the pilot provinces selected in the 1st Phase. In this study; The typology of the building, its suitability for the project and environmental factors will be examined. In addition, geophysical studies such as microtremor measurements will be carried out in selected schools within the limits of possibilities. Following these examinations, a total of 6 schools in one province, 2 from each province with three different ground types, will be selected and low-cost accelerometers will be installed in these schools.

In the EReS project, within the framework of cross-border cooperation, it is very important for the project teams to use a common database and make evaluations accordingly in terms of harmonizing the data. However, global databases, most of which have been produced as a result of scientific research supported by the EU, are also very useful and reliable data for a general evaluation.

The following data in Table 4 has been prepared by AFAD to be used in EReS Project fort he harmonization purpose.

Table 4. The available data to be used in EReS project will be provided by AFAD.

Data	Features
Earthquake Data	Earthquake data from the instrumental period recorded by our Presidency in the area of EReS project from 1900 to the present, approximately 67000 lines.
Strong Motion Data	Acceleration values recorded at various stations of 46 earthquakes with magnitude 5.0 and larger in the project area
Fault Information	Information on active faults produced and shared by MTA General Directorate
School Data	Location information and names of the schools participating in the pilot project

4.3 SCHOOL BUILDINGS DATA IN THE PILOT CASE SITE OF CANAKKALE

The school buildings data in Canakkale province central district has been gathered and presented according to the Construction Year, Construction material and Building height in Figure 41, Figure 42 and Figure 43 respectively.

Table 5. The school buildings data in Canakkale province Central district.

NO	PROVINCE	DISTRICT	CONSTRUCTION YEAR	CODE YEAR	NUMBER OF STOREY	CONSTRUCTION MATERIAL
1	Çanakkale	Merkez	2001	1998	2	RC
2	Çanakkale	Merkez	2017	2007	4	RC
3	Çanakkale	Merkez	1997	1975	3	Masonry
4	Çanakkale	Merkez	2011	2007	4	RC
5	Çanakkale	Merkez	2010	2007	4	RC
6	Çanakkale	Merkez	1963	1961	5	RC
7	Çanakkale	Merkez	2010	2007	4	RC
8	Çanakkale	Merkez	2003	1998	3	RC
9	Çanakkale	Merkez	2006	1998	4	RC
10	Çanakkale	Merkez	2017	2007	3	RC
11	Çanakkale	Merkez	2016	2007	4	RC
12	Çanakkale	Merkez	1985	1975	4	RC
13	Çanakkale	Merkez	2010	2007	4	RC
14	Çanakkale	Merkez	2014	2007	3	RC
15	Çanakkale	Merkez	1959	1953	2	Masonry/taş
16	Çanakkale	Merkez	1994	1975	4	RC
17	Çanakkale	Merkez	2005	1998	3	RC
18	Çanakkale	Merkez	1992	1975	4	RC
19	Çanakkale	Merkez	2011	2007	1	Masonry
20	Çanakkale	Merkez	1904		1	Masonry/taş
21	Çanakkale	Merkez	2010	2007	2	Masonry
22	Çanakkale	Merkez	1982	1975	4	RC
23	Çanakkale	Merkez	2013	2007	3	RC
24	Çanakkale	Merkez	1991	1975	3	RC
25	Çanakkale	Merkez	2002	1975	2	Masonry
26	Çanakkale	Merkez	2019	2018	4	RC
27	Çanakkale	Merkez			2	RC
28	Çanakkale	Merkez	2018	2007	4	RC
29	Çanakkale	Merkez	2017	2007	3	RC
30	Çanakkale	Merkez	1970	1953	2	Masonry
31	Çanakkale	Merkez	2014	2007	3	Masonry
32	Çanakkale	Merkez	2016	2007	4	RC
33	Çanakkale	Merkez	2018	2007	3	RC
34	Çanakkale	Merkez	2018	2007	4	RC
35	Çanakkale	Merkez	2020	2018	3	RC

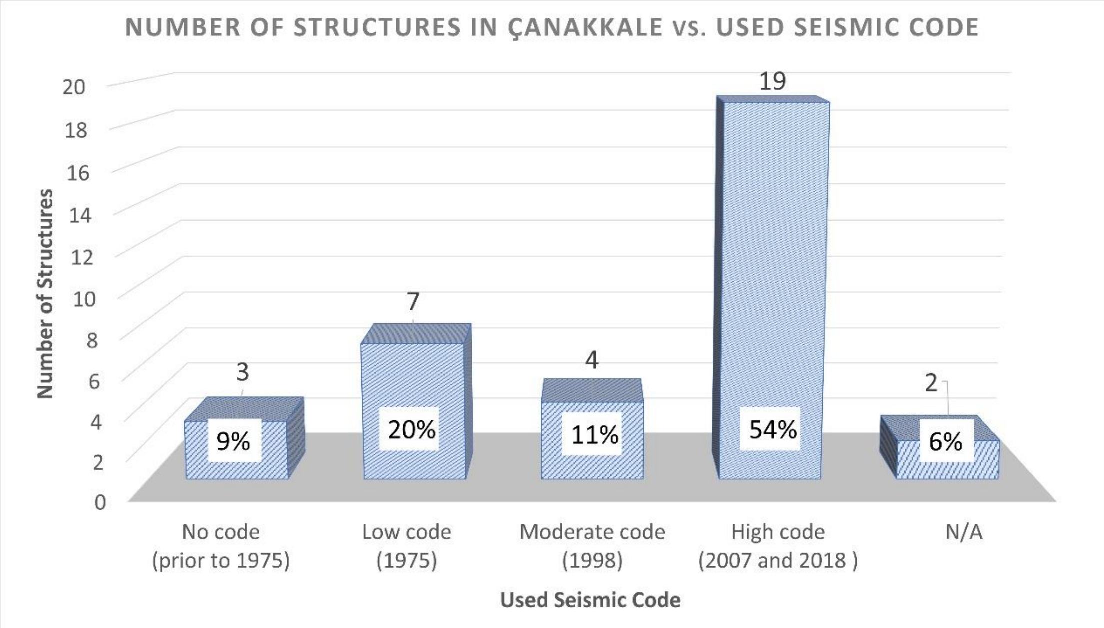

Figure 41. Construction year distribution with regard to design codes of the school buildings in Canakkale

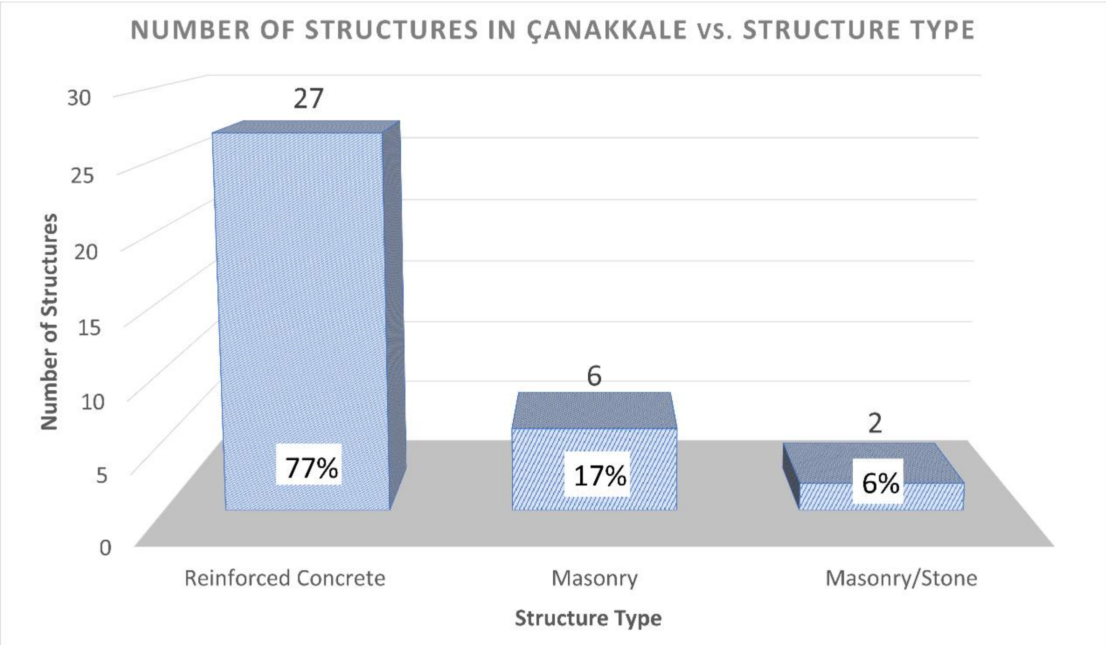

Figure 42. Construction material distribution of the school buildings in Canakkale

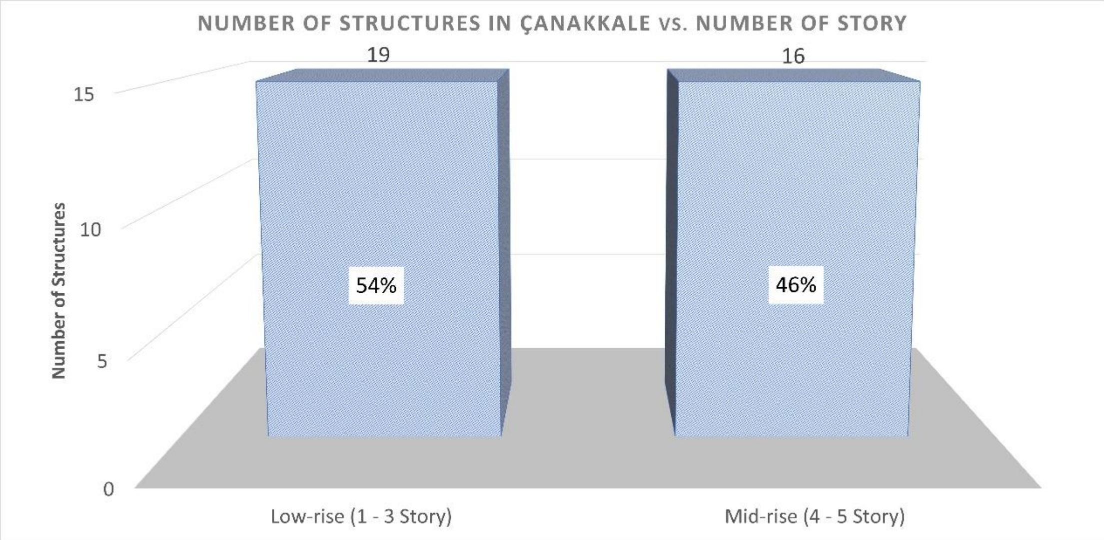

Figure 43. Building height distribution of the school buildings in Canakkale

In the Figure 44, the population distribution (number of students and number of teachers) in the school buildings in Canakkale province central district is provided.

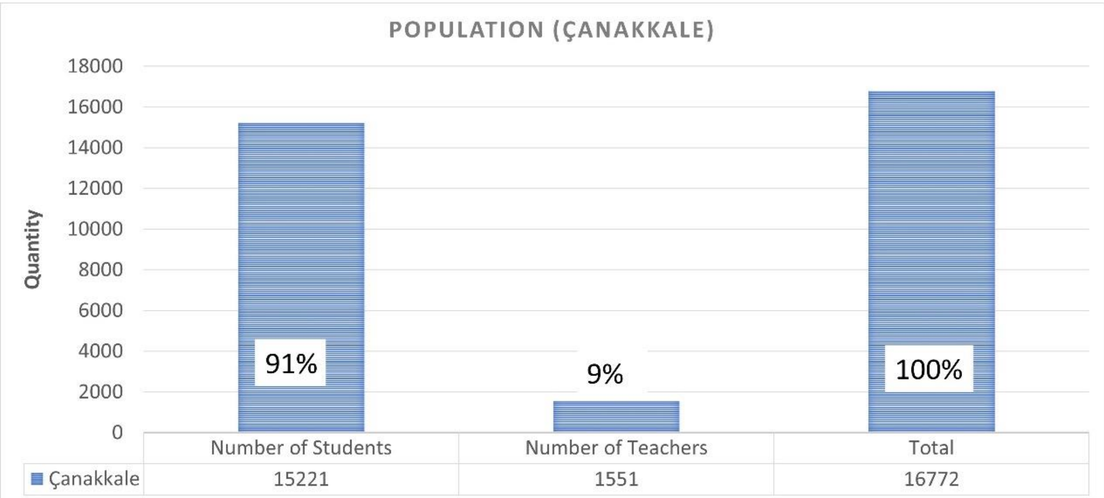

Figure 44. Population distribution of the school buildings in Canakkale

4.4 SCHOOL BUILDINGS DATA IN THE PILOT CASE SITE OF IZMIR

The school buildings data in Izmir province Balçova, Bornova and bayrakli districts has been gathered and presented according to the Construction Year, Construction material and Building height in Figure 45, Figure 46 and Figure 47 respectively.

Table 6. The school buildings data in Izmir province Balcova district.

NO	PROVINCE	DISTRICT	CONSTRUCTION YEAR	CODE YEAR	NUMBER OF STOREY	CONSTRUCTION MATERIAL
1	İzmir	Balçova	1996	1975	3	RC
2	İzmir	Balçova	2008	2007	3	RC
3	İzmir	Balçova	2005	1998	3	RC
4	İzmir	Balçova	1997	1975	4	Masonry
5	İzmir	Balçova	1990	1975	3	RC
6	İzmir	Balçova	1976	1975	4	RC
7	İzmir	Balçova	1963	1961	4	Masonry
8	İzmir	Balçova	1967	1961	4	RC
9	İzmir	Balçova	2005	1998	4	RC
10	İzmir	Balçova	1991	1975	4	RC
11	İzmir	Balçova	1999	1975	3	RC
12	İzmir	Balçova	1998	1975	4	RC

Table 7. The school buildings data in Izmir province Bornova district.

NO	PROVINCE	DISTRICT	CONSTRUCTION YEAR	CODE YEAR	NUMBER OF STOREYS	CONSTRUCTION MATERIAL
1	İzmir	Bornova	1996	1975	4	RC
2	İzmir	Bornova	1994	1975	4	Masonry
3	İzmir	Bornova	1955	1953	3	Masonry
4	İzmir	Bornova	1995	1975	4	RC
5	İzmir	Bornova	2002	1998	3	RC
6	İzmir	Bornova	1993	1975	4	RC
7	İzmir	Bornova	1969	1953	2	Masonry
8	İzmir	Bornova	1988	1975	4	RC
9	İzmir	Bornova	1980	1975	2	Masonry
10	İzmir	Bornova	2006	1998	2	Masonry
11	İzmir	Bornova	1986	1975	1	Masonry
12	İzmir	Bornova	1991	1975	4	RC
13	İzmir	Bornova			3	RC
14	İzmir	Bornova	2014	2007	4	RC
15	İzmir	Bornova	1998	1975	3	RC
16	İzmir	Bornova	1989	1975	4	RC

17	İzmir	Bornova	2014	2007	4	RC
18	İzmir	Bornova	2000	1998	4	RC
19	İzmir	Bornova	2002	1998	2	RC
20	İzmir	Bornova	1997	1975	3	RC
21	İzmir	Bornova	2004	1998	3	RC
22	İzmir	Bornova	1996	1975	4	RC
23	İzmir	Bornova	1992	1975	4	RC
24	İzmir	Bornova	2018	2007	3	RC
25	İzmir	Bornova	1999	1975	2	RC
26	İzmir	Bornova	1986	1975	4	RC
27	İzmir	Bornova	1973	1961	3	RC
28	İzmir	Bornova	1989	1975	3	Masonry
29	İzmir	Bornova	1972	1961	3	Masonry
30	İzmir	Bornova	2010	2007	2	Masonry
31	İzmir	Bornova	1992	1975	4	RC
32	İzmir	Bornova	1956	1953	2	RC
33	İzmir	Bornova	1985	1975	3	RC
34	İzmir	Bornova			3	RC
35	İzmir	Bornova	2001	1998	3	RC
36	İzmir	Bornova	2015	2007	3	RC
37	İzmir	Bornova	2020	2018	4	RC
38	İzmir	Bornova	1985	1975	3	RC
39	İzmir	Bornova	2020	2007	4	RC
40	İzmir	Bornova	2006	1998	3	RC
41	İzmir	Bornova	1998	1975	4	RC
42	İzmir	Bornova	2010	2007	3	RC
43	İzmir	Bornova	1974	1961	3	RC
44	İzmir	Bornova			3	Masonry
45	İzmir	Bornova	1986	1975	3	RC
46	İzmir	Bornova			2	RC
47	İzmir	Bornova	1987	1975	2	RC
48	İzmir	Bornova	2007	1998	3	RC
49	İzmir	Bornova	2006	1998	4	RC
50	İzmir	Bornova	2004	1998	3	Masonry
51	İzmir	Bornova	2016	2007	4	RC
52	İzmir	Bornova	1963	1953	1	Masonry
53	İzmir	Bornova	2017	2007	3	RC

54	İzmir	Bornova	2016	2007	3	RC
55	İzmir	Bornova	2013	2007	3	RC
56	İzmir	Bornova	2020	2018	3	RC
57	İzmir	Bornova	2019	2018	4	RC
58	İzmir	Bornova	2020	2018	4	RC
59	İzmir	Bornova	2021	2018	5	RC

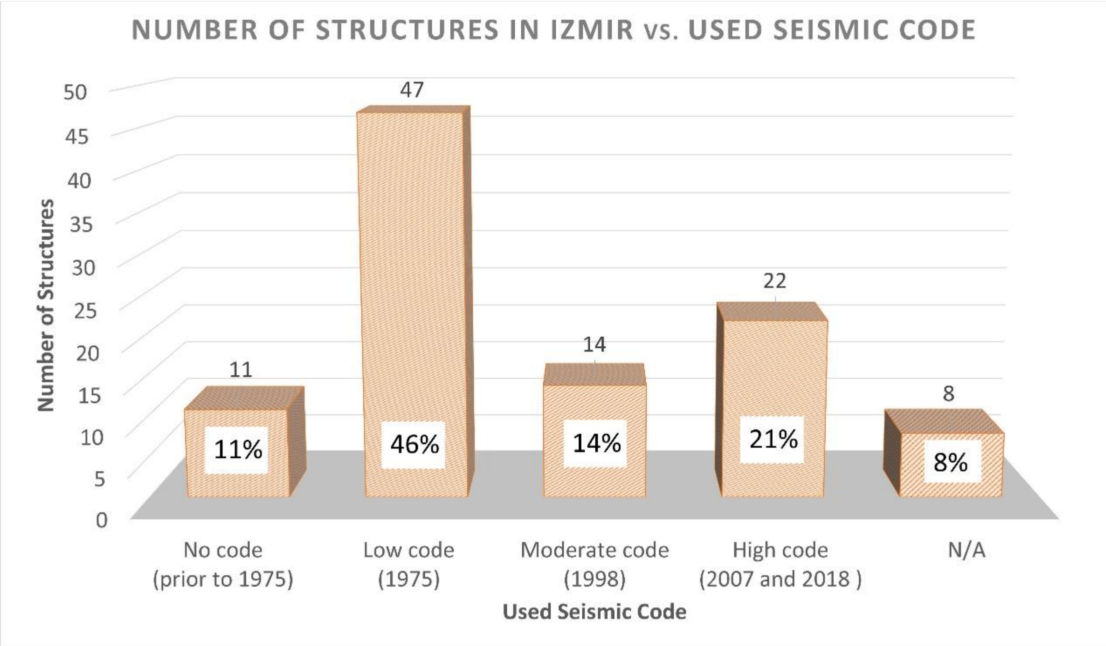

Figure 45. Construction year distribution with regard to design codes of the school buildings in İzmir

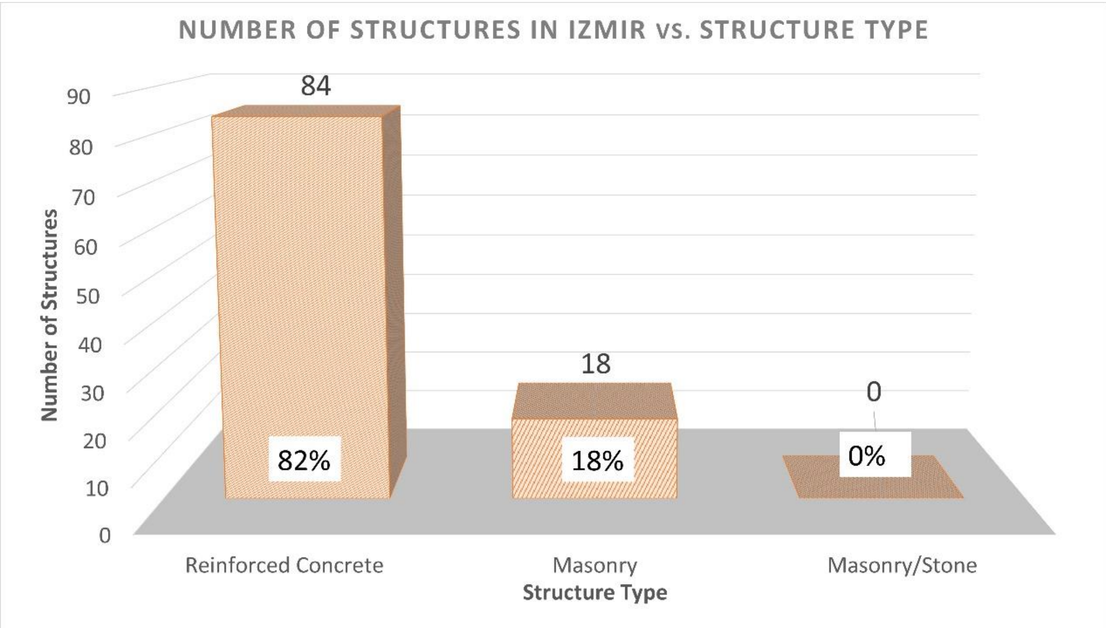

Figure 46. Construction material distribution of the school buildings in Izmir

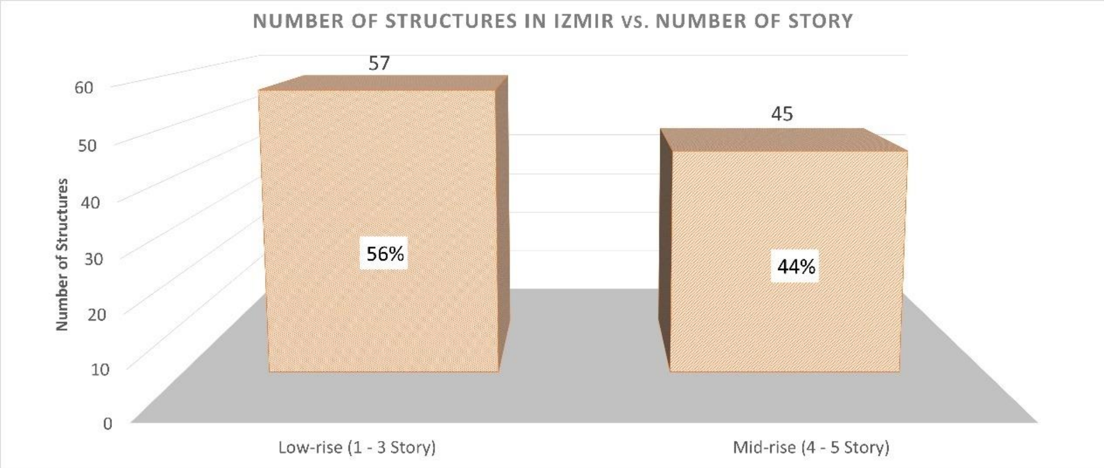

Figure 47. Building height distribution of the school buildings in Izmir

In the Figure 48, the population distribution (number of students and number of teachers) in the school buildings in Canakkale province central district is provided.

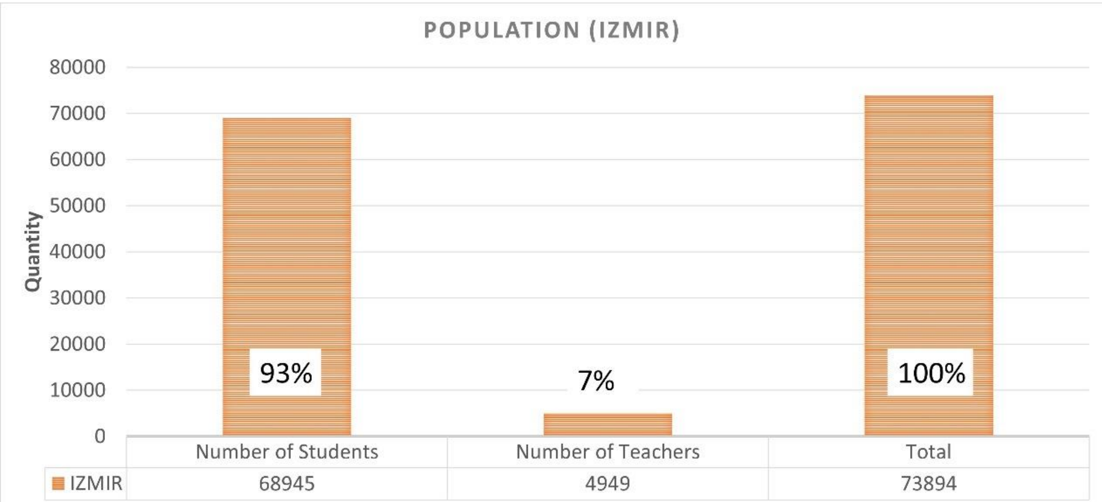

Figure 48. Population distribution of the school buildings in Izmir

5 SEISMIC RISK HARMONIZATION FRAMEWORK FOR THE GREECE-TÜRKIYE CROSS-BORDER AREA

As observed in sections 3 and 4, school buildings in Greece and Turkey share several common characteristics. These include older structures constructed with stone or brick masonry, newer buildings predominantly made from reinforced concrete, and typically low-rise (1–3 storeys; with a higher percentage of 4–5 storey mid-rise structures in Turkey). Despite these commonalities, noteworthy differences exist due to varying construction practices, different codes, and regulations applied in the two countries.

To establish a harmonization framework for seismic risk assessment in both Greece and Turkey, the participating teams from both countries have collaborated within the context of the EU-funded project REDACt (https://www.redact-project.eu). As part of this collaboration, they have developed a methodology and a corresponding software tool, REDAS v.1.2.3, capable of providing near real-time damage estimates for the building stock in urban areas. Capitalizing on the outcomes of this project, the methodology and tool will be expanded to encompass the risk assessment of school buildings as well.

After evaluating various building taxonomy schemes proposed in the literature, such as GEM, ESRM2020, HAZUS, WHE-PAGER, RiskUE, etc., for their applicability in describing the school building stock in the Greek-Turkey Cross-Border Area (CBA), it has been determined that the GEM taxonomy (Brzev et al., 2013) is well-suited for this purpose. This taxonomy has already been employed in the REDACt project, and fragility curves for GEM building typologies are available in the study conducted by Martins & Silva (2021). These functions have already been incorporated into the REDAS tool. Additional, school-specific building taxonomies and corresponding fragility curves will be explored, if deemed necessary, in later stages of the current project using the aforementioned tools.

The harmonized seismic hazard results, developed in the framework of WP2 of the current project (taking into account appropriate faults, GMPEs and soil Vs30 values), will be implemented in the REDAS software, along with shapefiles of the school building stock in the pilot case sites (for example the shapefiles including the school buildings in Alexandroupoli, presented in Figure 5) and the corresponding vulnerability functions (i.e., fragility curves). Screenshots of the configuration and the "Run Event" forms of the REDAS software, can be seen in Figure 49 and Figure 50, respectively.

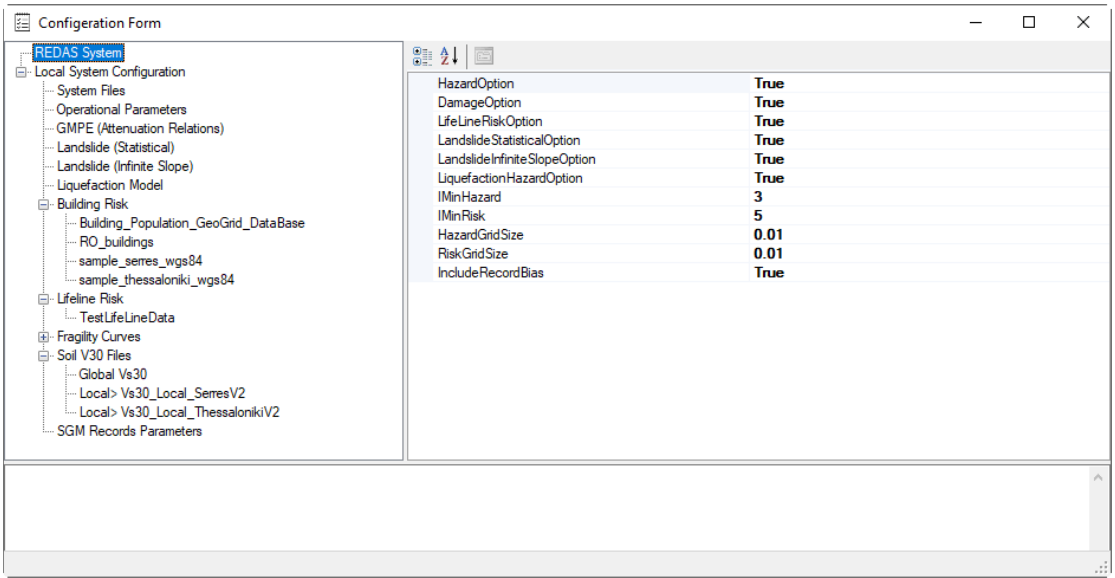

Figure 49. Configuration section of REDAS interface for scenario-based analysis

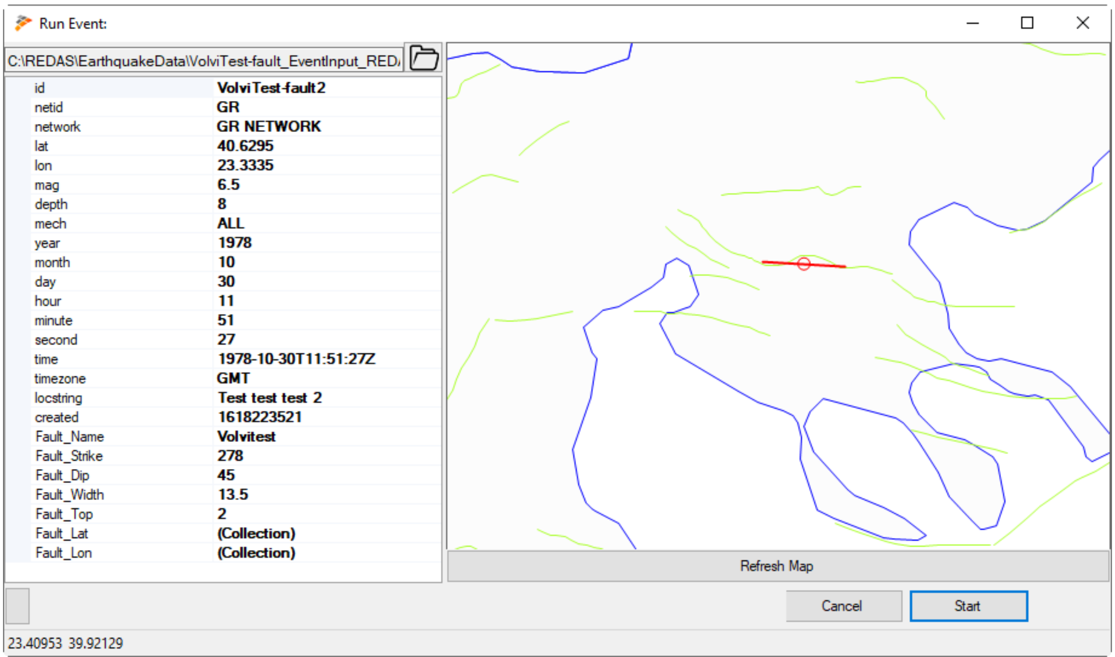

Figure 50. Run section of REDA.p interface for scenario-based analysis

The outcomes of this harmonized framework will encompass the probabilities of school buildings experiencing predefined damage states, determined by the corresponding fragility curves. These damage states range from no damage to the collapse of the structure (the REDAS software currently supports 4 damage state vulnerability schemes).

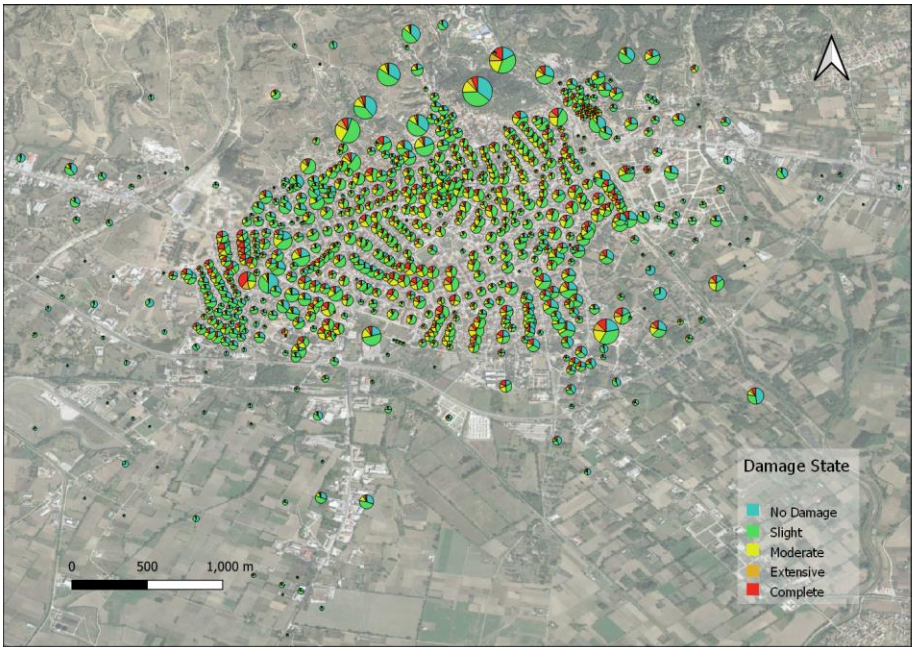

Figure 51. Example of spatial distribution of damage states for the building stock of Serres (REDACt, D.T3.3.1)

An example of the spatial distribution of damage states estimated for the building stock in the city of Serres, Greece is presented in Figure 51. With the corresponding data for school buildings available in a pilot case site, there is an opportunity to investigate the seismic performance of these school buildings in comparison to the overall building stock in the same area. Such cases will be explored in later stages of the current project.

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