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Prof. Dr. Özlem PARLAK BİÇER

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No: 22/A Çankaya/ANKARA Tel: 0312 384 80 40

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CONTENTS

INVESTIGATION OF NANOTECHNOLOGICAL DEVELOPMENTS THROUGH CONCRETE MATERIAL

Yenal TAKVA[1]

Fulya GÖKŞEN TAKVA[2]

1 Gazi University, Faculty of Architecture, Department of Architecture, yenaltakva@gazi.edu.tr, ORCID iD: 0000-0002-5330-2980

2 Gazi University, Faculty of Architecture, Department of Architecture, fulyagoksen@gazi.edu.tr, ORCID iD: 0000-0002-9754-0956

1. Introduction

Nanotechnology can be conceptually defined as the ability to create new structures at the minor scale using tools and techniques that allow understanding and processing of matter at the nanoscale, generally from 0.1 to 100 nanometers (Zhu et al., 2004; Silvestre et al., 2016). Along with technological developments, the nanotechnology revolution in recent years; has dramatically affected the construction industry and different scientific fields such as chemistry, engineering, and biology. Rapidly developing multifunctional and innovative materials can give building materials extraordinary properties (Takva et al., 2023a; Takva et al., 2023b). Nanotechnology contributes to many features such as improving production, reducing the number of production stages, material volume or weight, increasing durability by preventing material damage, and improving the performance and quality of existing products (İlerisoy & Takva, 2017; Takva et al., 2023c).

Material selection is an essential issue for the construction industry (Çakıcı & Takva, 2023). Nanotechnology has an extensive application area, including the design, production, and application of nanomaterials and nanostructures. Concrete is a cement-based multiphase composite material widely used for many years. It constitutes the primary material of load-bearing system elements today and in the future. Cement is an artificial mixture of fillers (sand, slag, ash, zeolites, etc.), water, and special additives. It has relatively low cost and energy density (Yang et al., 2023). As structural materials, cementitious materials are susceptible to cracking and have no functional properties. Nanotechnology can be incorporated into cementitious materials to solve these problems (Singh et al., 2017). Features such as durability of building materials, high strength, permanent and rapid constructability, and reduction of adverse effects on the environment are possible in light of nanotechnological developments (Takva & İlerisoy, 2023a; Takva & İlerisoy, 2023b).

The main focus of modern applications in concrete technology is to minimize material and energy costs and thus obtain concrete with the desired technical and technological properties (Yang et al., 2023). Nanotechnology encompasses two basic approaches. The first of these is the top-down approach. This approach is where large structures are reduced to the nanoscale but retain their original properties without atomic-level control or are deconstructed from larger structures into smaller, composite parts. Second, Drexler et al. (1991) use a bottom-up approach called molecular manufacturing or molecular nanotechnology. Here, materials are designed through a process that involves the control of atoms or molecular components (Sanchez & Sobolev, 2010). It is the dimensional enlargement of material atoms and molecules using chemical synthesis methods (Gordijn, 2005) (Figure 1). While most contemporary technologies rely on a "top-down" approach, molecular nanotechnology promises significant breakthroughs in national security, medicine and healthcare, biotechnology, information technology, electronics, energy, materials, and manufacturing (Sanchez & Sobolev, 2010).

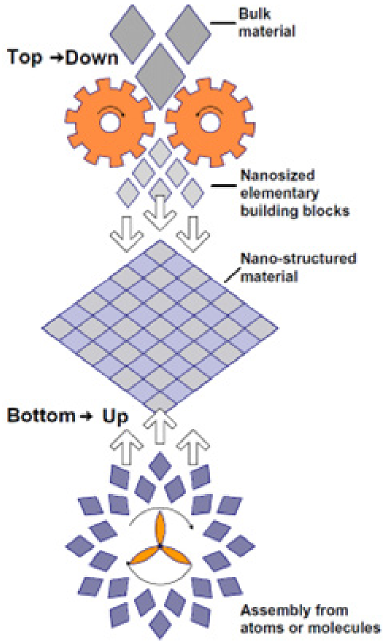


Figure 1. There are two basic nanotechnological approaches (Sanchez & Sobolev, 2010).

The primary purpose of nanotechnology is to benefit from the different properties of nanomaterials developed using special production techniques and to give them extraordinary properties by controlling the internal structures of large-scale materials at the atomic level (Gullapalli & Wong, 2011).

Engineering, architecture, and the construction industry, which includes these disciplines, constitute a wide application area for nanomaterials and nanotechnology. This study investigated the possibilities of using nanotechnological development on concrete material. The study aims to examine the nanotechnological developments used in concrete systematically. In the light of the literature review carried out in this context, nanomaterials used in concrete were investigated and their contributions to concrete were examined. As a result of the evaluations, it has been seen that many nanomaterials that increase the pressure, tensile strength, and resistance of concrete to environmental conditions make concrete a highly developed material. It has been observed that nanomaterials used in concrete increase its strength. In addition, it has been determined that it contributes to improving workability thanks to its properties that increase concrete fluidity.

2. Nanomaterials Used in Concrete

Those that have been given superior properties by nanotechnology and are widely used in the context of nanomaterials are given in Figure 2.

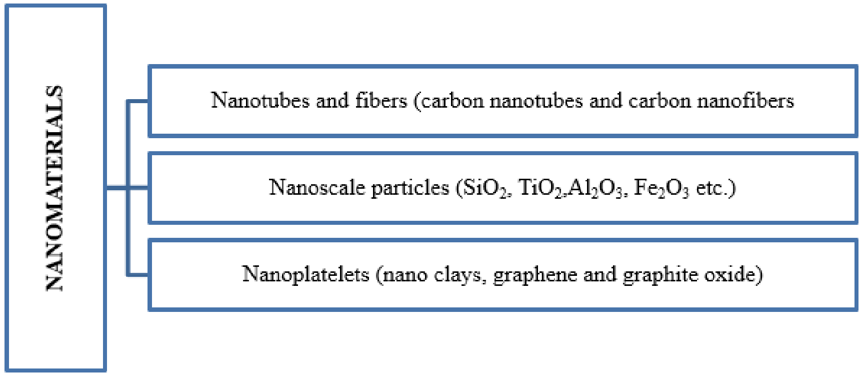


Figure 2. Commonly used nanomaterials (Mukhopadhyay, 2011; Han et al., 2015; Shah et al., 2016; Du et al., 2019).

In this study, nanomaterial applications used in the concrete industry were examined and the developments in concrete properties with this technology were analyzed in the light of literature research.

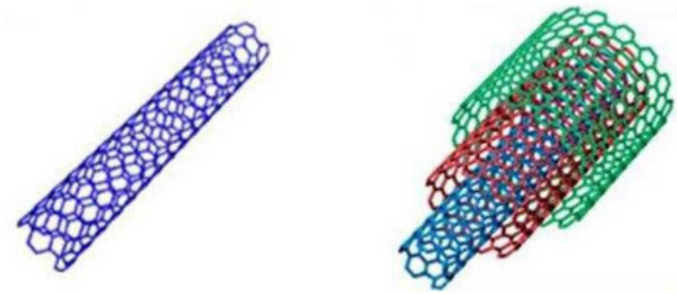
2.1. Carbon Nanotubes

Carbon nanotubes; It has a cylindrical shape between approximately 1 and 50 nanometers and is classified as single (SWCNT) or multilayer (MWCNT) (Figure 3). Their lengths can vary from a few micrometers to 550 micrometers and their diameters can vary up to 550 micrometers. It has been observed that the mechanical properties of concrete are significantly improved by adding small amounts of carbon nanotubes to cement (Wang et al., 2009).

Carbon nanotubes, which consist of graphite planes wrapped around tubes, have a cylindrical surface with carbon atoms at the corners and regular hexagons. The use of nanoparticles and carbon nanotubes in concrete has brought new and essential properties to the material (Wang et al., 2009).

Carbon nanotubes have superior properties such as higher stability and surface chemistry because they have more robust durability and elastic deformation than steel and higher conductivity than copper (Lee et al., 2010).

The compressive strength and bending strength of concrete have increased with multilayer nanotubes. Compared with traditional samples, it provided an advantage of +8 N/mm2 in bending strength and +25 N/mm2 in compressive strength (Alsafar, 2014).



a) SWCNT b) MWCNT

Figure 3. Representation of SWCNT and MWCNT (Pitroda & Jethwa, 2016)

It has been found that nanomaterials, especially NCMs, can improve or modify the durability, mechanical, and functional properties of cementitious materials thanks to their composite effect and excellent intrinsic properties (Han et al., 2015).

Carbon nanotubes, which have many advantageous mechanical and electrical properties such as high strength and high conductivity, are very attractive for producing fiber-reinforced concrete. The incorporation of fibers at the nanoscale allows matrix cracks to be controlled at the nanoscale (Hanus & Harris, 2013). Carbon nanotubes (CNTs) can withstand breaking and bending effects without breaking. CNTs are expected to produce significantly tougher and stronger cement composites than traditional reinforcement materials. This includes glass or carbon fiber (Singh et al., 2017). Because of their aspect ratio and size (ranging from 1 nanometer to tens of nanometers), CNTs can be dispersed on a much finer scale than standard fibers. In this way, it provides more effective crack bridging at the first stage of the crack (Figure 4) (Hanus & Harris, 2013).

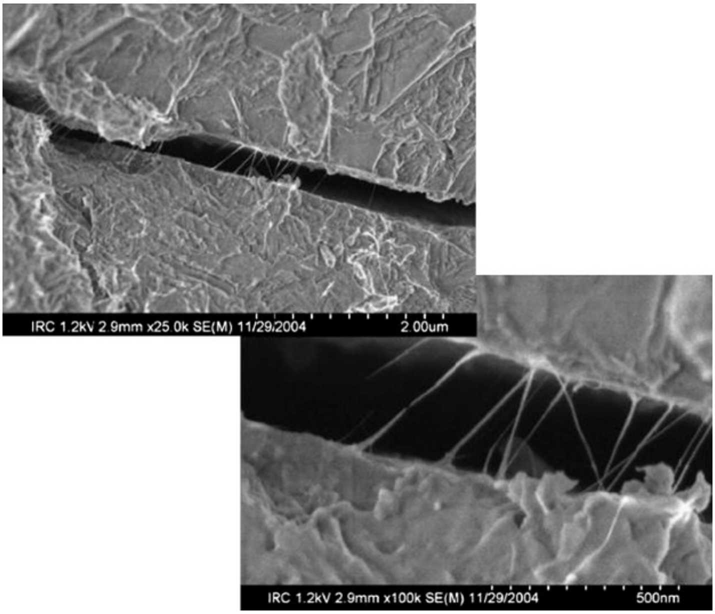


Figure 4. Crack bridging in CNT composites (Sanchez & Sobolev, 2010).

2.2. Nanoparticles

Particles ranging in size from 1 to 100 nanometers can be defined as nanoparticles (Gordijn, 2005). Silica, whose chemical formula is SiO2, is a nanoparticle used in concrete. This compound has a crystal structure, just like a diamond. This nanoparticle has a relatively high melting and boiling point and is abundant in the earth's crust. It exists in crystalline and amorphous forms (Ji, 2005).

The type and size of silica particles are essential for producing quality concrete. With the addition of this particle to the cement mortar, there is an improvement in pressure and bending strength compared to traditional mortar. In addition, it prevents water from penetrating the concrete by controlling the CSH (calcium silicate-hydrate) decomposition reaction in concrete, thus increasing its strength (Ji, 2005).

SiO2 (Figure 5) increases concrete durability and workability. SiO2 has been found to accelerate hydration in concrete and is more effective than silica fume in increasing strength (Sanchez & Sobolev, 2010). It has been observed that a 10% increase in the compressive strength of cement mortars is achieved with the addition of 15% silica fume, and the addition of 10% SiO2 with dispersing agents increases it up to 26% in 28 days (Li et al., 2004a). SiO2 acts as an activator that promotes pozzolanic reactions and a filler that improves the microstructure (Jo et al., 2007).

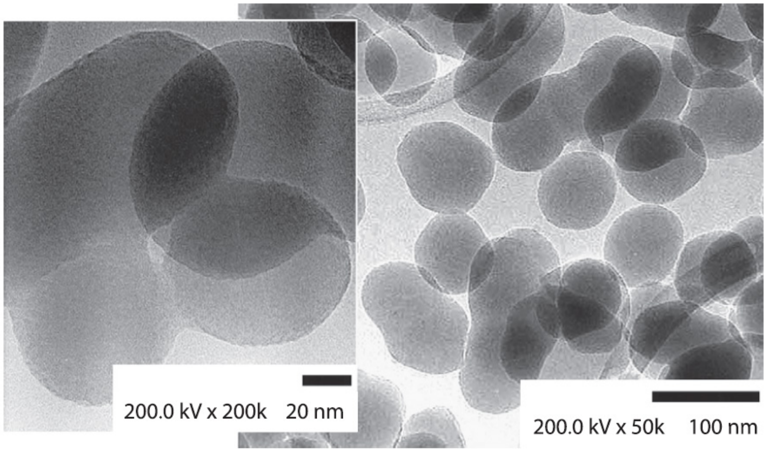


Figure 5. Spherical SiO_2 particles appearance (Sanchez & Sobolev, 2010).

Titanium dioxide (TiO2) is a nanoparticle that improves concrete material properties (Figure 6). In most applications, the concrete surface is exposed to liquids such as water, oil, mineral solutions, solvents, etc. In this case, it causes corrosion in concrete exposed to environmental influences. When concrete is exposed to liquid, the pores absorb most of the liquid due to capillary forces. Having water-repellent properties is an essential factor in increasing concrete durability. TiO2 is a reflective coating material and a nanoparticle that can decompose organic pollutants and volatile organic compounds through powerful photocatalytic reactions. TiO2 has hydrophilic properties and thus can ensure the material maintains its whiteness and brightness for a long time (Kazempour, 2016).

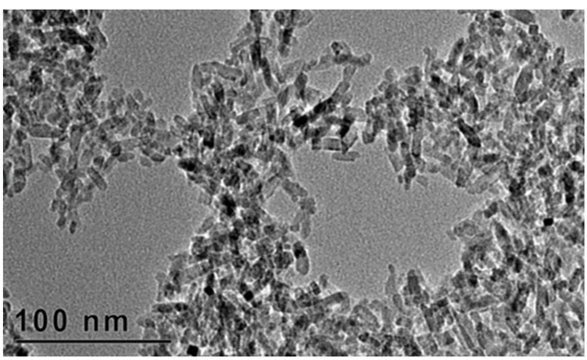


Figure 6. TiO_2 molecular structure (Internet-1)

In addition to providing the additional benefit of helping to clean the environment, TiO_2 has also been proven to be very effective at self-cleaning concrete. Concrete containing TiO_2 triggers the photocatalytic degradation of pollutants such as NOx, carbon monoxide, VOCs, chlorophenols, and aldehydes from vehicle and industrial emissions. Many companies currently produce self-cleaning and de-polluting concrete products for building facades and road covering materials (Sanchez & Sobolev, 2010).

Another nanoparticle used in concrete, FerrousOxide (Fe_2O_3) (Figure 7), was found to increase concrete compressive strength and bending strength (Li et al., 2004a; Li et al., 2004b). A delay in concrete setting time was observed (Li et al., 2004b). It reduces the total number of pores in the concrete and increases its abrasion resistance (Saleem et al., 2021).

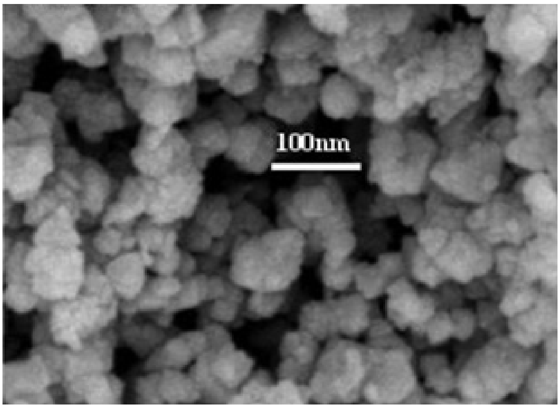
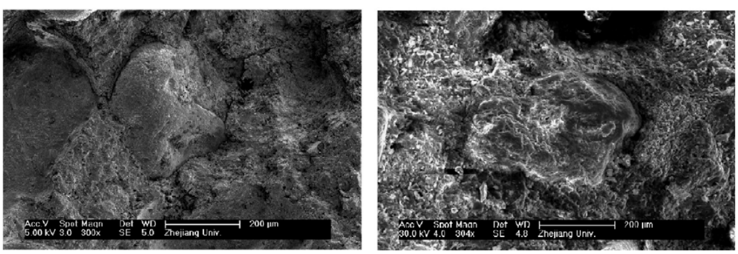


Figure 7. Image of Fe2O3 nanoparticles with the electron microscope (Internet-2)

Li et al. (2006) stated in their study that when the nano-alumina (Nano-Al_2O_3) ratio was 5%, the modulus of elasticity of cement compounds increased by 143% in 28 days. When the nano-alumina ratio was 7%, the compressive strength of the composites increased by 30% in 7 days. They observed that by adding nano-alumina to the mortars, the cement pores decreased, and as a result, the elastic modulus and compressive strength of the nano-alumina mortar increased. Figure 8 shows the visual of the test sample and the mortar with 5% nano-alumina added. In Figure 8b, it can be seen that the interfacial transition zone has increased compared to the image in Figure 8a.



a) 0% nano-alumina b) 5% nano-alumina

Figure 8. The electron microscope image of mortars hydrating for 28 days (Li et al., 2006)

Another option in the world of nanotechnology and concrete is the addition of fly ash to the concrete mixture. Fly ash is known as supplemental cement material or SCM. Although fly ash is not a groundbreaking phenomenon in concrete, it is vital to the progress of modern concrete technology. Fly ash consists of small spherical-shaped particles that can fill holes quickly. In this way, it contributes to obtaining strong concrete by adding it to concrete (Brightson et al., 2013a). The dimensions of fly ash microspheres using electron microscopy are given in Figure 9.

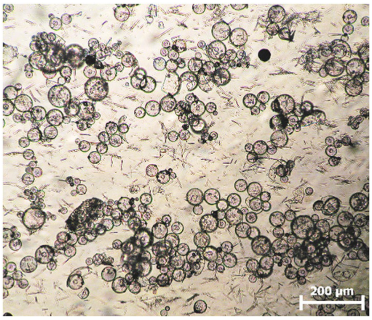
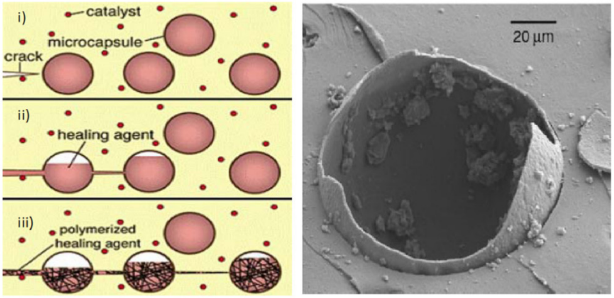


Figure 9. Micrograph of fly ash microspheres (Yang et al., 2023).

Concrete is a brittle material and is very difficult to repair in case of cracking. In the studies, particular bacteria that can live in an alkaline (basic) concrete environment were used to repair the cracks in the material so that the concrete could renew itself. Examples of these are bacteria known as Bacillus, which live in alkaline lakes in Russia and Egypt. These bacteria are embedded in small ceramic cavities and incorporated into the wet concrete mixture. These bacteria, which remain dormant in concrete, become active with water leaks and crack formation. The calcium carbonate from the reactions penetrates the cracks and closes the pores (Figure 10). By adding the anaerobic microorganisms used in this application to the water and concrete mixture, the 28-day strength of the concrete increases by 25% (Kazempour, 2016).



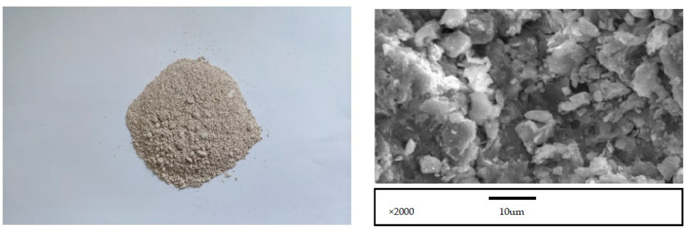
a) b)

Figure 10. (a) Microcapsule process: (i) Crack formation; (ii) Release of healing agent; (iii) Crack repair process; and (b) image of ruptured microcapsule (Vijay et al., 2017).

2.3. Nano Clay

When the concrete using nano clay is compared to conventional concrete, it can be seen that all microholes are filled. Nano clay is a thousand times smaller than the materials used in traditional concrete. This reduces the cement used, and a certain percentage of the cement used is saved. Figure 11 shows the appearance of nano clay with the naked eye and electron microscope.

Using nano clay in concrete improves its properties in both the plastic and hardened stages. In this case, a more durable concrete is obtained. Nano clay added to concrete; It has been accepted that being small, evenly spaced, and homogeneously placed will act as a crack preventer in the material and significantly improve the concrete's static and dynamic properties. With the addition of nano clay, post-crack tensile strength), fatigue strength, impact strength, and ductility performance of concrete structures increase. As a result of the experiments, concrete with nano clay addition has higher compressive, split tensile, and flexural strength (Brightson et al., 2013b).



a) b)

Figure 11. (a) Nano clay; (b) nano clay in electron microscope (Qian et al., 2021)

3. Application and Evaluation

One of the most critical application areas of nanotechnology is undoubtedly the construction industry. Events and structural elements acting at the nano and micro scale significantly affect the mechanical behavior of concrete. With the nanomodification of concrete material, the potential to open new areas of use of concrete and new classes of materials is possible. Table 1 shows the developments in concrete properties and the nanomaterials used.

Table 1. *Nanomaterials and advances in concrete properties*

Nanomaterials	Property Improvements in Concrete
Carbon nanotubes	• Increase in compressive strength and bending strength • Improvement in mechanical and functional properties • It is desirable for the production of fiber-reinforced concrete • Controlling matrix cracks at the nanoscale (Provides crack bridging) • Production of tougher and stronger cement composites
SiO_2	• Increase in compressive strength and bending strength • Prevents water from penetrating concrete • Increases concrete workability • Accelerates hydration in concrete • Promotes pozzolanic reactions and as a filler that improves the microstructure
$TİO_2$	• Having water-repellent properties • Very effective in self-cleaning of concrete • Pollution-removing properties • Increases the abrasion resistance • Compressive strength improves • Concrete durability increases
Fe_2O_3	• Compressive strength and bending strength increases • Decreases the total porosity of concrete • Increases the abrasion resistance of concrete
Al_2O_3	• Compressive strength improves • Increases the modulus of elasticity of cement composites • Reduces cement pores

Nanomaterials can improve the life cycle and performance of concrete structures. Scientists are focusing on developing manufacturing technology to produce nanomaterials to make nanomaterials easily accessible economically on a commercial scale (Saleem et al., 2021).

4. Conclusion

Nanotechnology is widely used in the construction industry, as in many disciplines, and significantly improves the material properties of concrete.

It contributes to extending the quality and performance of concrete and its physical life. At the same time, it offers opportunities for economical use of resources within the scope of efficient production. The widespread use of nanotechnological features and developments provides the opportunity to save time in the construction industry. It is also possible that problems in the construction sector will decrease, and thus, long-term costs will be affected. Following innovative developments professionally and benefiting from the opportunities offered is necessary.

The study provides a valuable perspective on the usage possibilities of nanotechnology in concrete. Concrete and significant developments of the current situation in concrete are reviewed. Nanotechnology; With the increase in concrete performance, and new information on service life and improvement, it is promising to develop sustainable materials with mechanical and functional properties.

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THE EFFECT OF GREEN NETWORKS ON WATER MANAGEMENT IN URBAN STREETS

Seyhan SEYHAN[1]

Elif BAYRAMOĞLU[2]

Mahmut Muhammet BAYRAMOĞLU[3]

1 Seyhan SEYHAN, Res. Assist., Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon / Turkey, seyhanseyhan2@gmail.com, 0000-0002-6046-5024

2 Elif BAYRAMOĞLU, Prof. Dr, Karadeniz Technical University, Faculty of Forestry, Department of Landscape Architecture, Trabzon / Turkey, elifsol_@hotmail.com, 0000-0002-6757-7766

3 Mahmut Muhammet BAYRAMOĞLU, Assoc. Prof. Dr., Karadeniz Technical University, Faculty of Forestry, Department of Forest Engineering, Trabzon / Turkey, mahmudtr@gmail.com, 0000-0002-0870-5094

1. INTRODUCTION

Cities are places that have an impact on the social life of people. Urban spaces and the meanings attributed to these spaces are among the most important elements of communication between society and individuals. Urban spaces, green areas, squares, streets and buildings enable the city to be perceived together as a whole (Erdönmez & Akı, 2005). These spaces can be analysed as private spaces and public spaces (Düzenli & Alpak, 2023). Public and private spaces interfere with each other functionally and depending on usage. The intermediate zones formed in this way also form semi-private and semi-public spaces that can be considered as transition spaces (Perinçek, 2003; Düzenli et al., 2018). Urban space is a whole formed by buildings, perceived by urbanites and related to all urban events (Alpak et al., 2019). The effects of cities on the social life of people are important. As suggested by Wirth, the city is not only a place where houses and workplaces increase, but in this sense, it is a place that gathers and transforms many remote communities of the world in the form of a circle and network of different areas, people and activities, initiating and controlling the centre of economic, political and cultural life (Wirth, 1964).

They are public spaces where private and public are intertwined or which offer rich experiences to people as the first transition from the private to the public sphere. The most prominent and important feature of public spaces is that they are accessible to everyone. The two basic elements of urban and public space are streets and squares. Urban streets are part of the urban fabric. Urban streets are the areas where people with a heterogeneous structure come into contact with each other. It usually extends along its length surrounded by buildings on both sides. Streets direct and shape the urban environment and provide us with freedom of movement, which is very important for urban life (Gür, 1996). In the formation of the social fabric, streets are the main component of the urban structure and the basic outer space of the city. The two main features of the street in relation to form are that it is both a road and a space at the same time. Throughout the periods, streets have provided public open spaces for urban societies (Gehl, 2001).

However, rapid urbanisation and climate change, especially in recent years, have put natural and cultural landscape resources both within and around urban areas under pressure. Rapidly spreading sustainable urban development has increased the impact on urban landscape areas in the context of ecological values. In this context, urban landscape has started to be evaluated in terms of green infrastructure systems. Green infrastructure systems are considered as an important component of sustainable urban development (Güneş & Şahin, 2015).

Urbanisation is the increase in the density of human and building units in certain areas and their spread outwards. Half of the world's population is concentrated in cities, which are areas of concentration. With the development of technology and industry, as a result of rapid population growth, human pressure on the ecosystem has increased and natural environments have faced extinction and loss of renewable power (Forman, 2014). However, urban ecosystems created by human influence have become completely unnatural. The "urban climate", which is caused by the coating of surfaces with impermeable structural surfaces and the increase in particulate matter and emission rates, especially due to road networks, has limited atmospheric changes that cause effects such as higher air and surface temperatures, disturbances in radiation balance, low humidity values and accumulation of pollutants derived from a wide variety of sources (Aksu, 2021).

1.1. Urban Streets

A city is a place which is in continuous social development and where the needs of the society for settlement, shelter, commuting, rest and recreation are met. It is a settlement unit which is more dense in terms of population compared to villages and consists of small neighbourhood units (Keleş, 1980). The city is first and foremost a meeting place for people and a place of confrontation with the society. City streets, which are considered as urban space, provide function and circulation with the dimensions of the space boundaries. In urban space, streets are communication networks and squares are nodes. The formal characteristics of streets and squares are identical; they differ from each other only in the dimensions of their spatial boundaries, functions and circulation patterns. Streets and squares have been the most important factors in the social life of cities throughout the ages (Aru, 1965).

Streets are the smallest units that provide mobility in the city. A street network that puts people at the centre and provides equal access for everyone makes the city more livable. The street is the place where people can be outside. Streets are places for social encounters and commercial exchange. There is movement on the street: It is possible to pass by, stand, sit and watch what is happening. Everyone can use the street. The street harbours the possibility of seeing and being seen. It is the social centre that determines urban character and urban identity (Jacobs, 1996). The most important function of open urban spaces is to create a social life (texture) between buildings. This social life enables people to communicate and socialise with each other when more than one person is together in a public space(Figure 1).

Figure 1. Urban Streets (Url-1;Url-2)

It includes children playing, celebrations, conversations, collective actions and passive communication - seeing, hearing - by providing a social fabric. Streets differ according to societies and geography. In some cities, the concept of street is unique to that city. In Venice, there are canals instead of streets. The doors of the houses open directly to the canals. The scaffolding of each house is the door facing the canal. These canals also serve the ecosystem of the city (Döllük, 2005).

Urban streets are the main external space of the city and the main component of the urban structure. Streets have two basic characteristics related to form: they are both roads and spaces at the same time. They connect houses and workplaces and form living spaces." Streets, open public spaces formed by the physical environment, are among the most important elements that make the city recognisable and exciting, as mentioned by Jane Jacobs (Erdönmez & Akı, 2005; Alpak & Düzenli, 2018). Urban streets are also interfaces that allow the green texture to accompany the city. As an extension of rural areas, green textures can extend to the city in this way. Urban street planted areas create a corridor effect. By creating an ecological effect in the city, it enables the effects of human beings on the spatial pattern to be revealed. It focuses on spatial heterogeneity and pattern-process relationship. They are the stepping stones of nature. With these structures, they link the urban green system with the surrounding natural systems, serve recreational purposes, contribute to the regulation of microclimate conditions, balance negative effects such as emissions and noise, have vital importance for living things, provide food and shelter, green corridors with high ecological value provide the flow between living environments, undertake important tasks in terms of ecosystem cycles in urban areas, and increase the quality of life of green areas and people (Aksu, 2021).

1.2. Urban Corridors and Green Networks

Ecological corridors and connections of cities are the integrating elements of rural and urban green tissue. By considering corridors and connections as a whole, a healthy ecological integrity that complements each other will be realised. One of the most important elements of urban corridors is ‘urban roads’ (Çetinkaya, 2013). One of the most important elements of urban corridors is undoubtedly urban roads. Urban road networks are indispensable facilities of cities and should be carefully considered in terms of their corridor potentials and the aesthetic, ecological and economic values they add to the city in this sense. Urban road networks also determine the quality of the corridors they form. In this sense, applications that enrich urban corridors in terms of function and aesthetics gain importance. Urban road networks supported with vegetative materials assume the roles of binding and complementing between open and green areas such as squares and parks, which are the elements of another urban corridor, and thus the green texture spreads to the city through corridors (Figure 2)(Yerli & Kesim, 2009).

Figure 2. Dasha River Ecological Corridor-Shenzhen, China(Url-3; Url-4)

Urban corridors (Figure 3) serve as green infrastructure systems within the city. Green infrastructure applications are preferred in terms of reducing energy costs, reducing damage caused by floods, protecting public health and environmental health. Most importantly, today they are evaluated in terms of water management. Their ecological, socio-cultural and economic contributions to the city and its inhabitants are indisputable. The loss of these areas means both a decrease in our quality of life and deprivation of the natural services they provide at no cost (Yaralıoğlu & Asilsoy, 2021).

Figure 3. Urban corridors(Url-5;Url-6)

Within the urban ecosystem, these corridors, due to their linear character, shield themselves from the negative effects of transport networks along the line. The most important systems that contribute to the continuity of this regulating effect are the green areas accompanying the road networks. These areas have vital functions such as connecting green units within the urban ecosystem, providing a living environment for living organisms, and balancing the negative effects of road networks. They lead the way in green road and corridor designs, which should be evaluated sensitively in urban environments and designed to support the urban ecosystem. They connect other point green units in the urban ecosystem and thus encourage species mobility and biodiversity (Aksu, 2021).

Green networks (Figure 4), which have high aesthetic value, are also important systems for the sustainability of natural and cultural values (Kurdoğlu et al., 2016). It is one of the elements that increase the quality of life by creating open spaces that allow recreation opportunities. Greenways can be of different typologies; Urban riverside greenways are belts that are usually created by redevelopment, rarely defining the remnant areas on the waterfront. Recreational greenways are natural corridors, such as footpaths, with a variety of long lines, recreational or recreational purposes. Ecologically important natural corridors, natural areas such as rivers and streamsides, provide opportunities for wildlife migration and species exchange, and for walking and hiking in the natural landscape. Scenic and historic routes are usually pedestrianised routes along the road. Extensive greenway systems or networks, natural landforms such as valleys and hills, are open spaces that provide alternative urban or regional green infrastructure (Little, 1995). Wildlife corridors within cities are valuable routes for greenways due to their ecological importance. These corridor lines are areas that allow fauna migrations, interspecies mobility, studies on wildlife and nature walks for tourism or educational purposes (Tokuş, 2012).

Figure 4. Green networks(Url-7)

1.3.Urban Green Networks-Water Management Relationship

Urban green networks are also called ecological networks. It first emerged in the Netherlands in the 1970s. In order to sustain and maintain habitats in Europe, a model that could sustain the natural ecosystem was needed. In this context, ecological networks were established. One of the most effective and important functions of networks is to protect and improve biodiversity (Hepcan C. 2008).

There are three main components that should be present in an urban ecological network system (Figure 5). These are core zones or repair zones, corridors/connections and buffer zones. Core zones are inner zones that protect important habitats, species and ecosystems. Corridors and linkages are the lines that connect core areas with belts and corridors that provide communication and communication opportunities. They undertake the task of providing habitat for fauna and flora species in landscapes where people are densely populated (such as urban environments) (Bennet, 2003).

Figure 5. Urban Ecological Network System(Url-8;Url-9)

Urban green networks; linear parks arranged for recreational purposes in urban environments are also among the corridor typologies in ecological networks. In addition, it takes precautions against the damage of natural resources such as water resources management, wildlife areas, continuity of existing vegetation. Problems that are among the main problems of the city, such as urban infrastructure creation, can also be corrected (Jongman, 2004). These networks are especially important in areas where urbanisation has reached a level that threatens the natural environment due to their sustainability feature (Tokuş, 2012; Bayramoğlu et.al.,2019). Sustainable development in the urban area is realised by planning green network systems to the extent that ecology is introduced into the city.

There is a strong relationship between urban green networks and water management in cities. Besides their natural and functional benefits on the ecosystem, they play an active role in creating cultural connections between landscapes and open spaces. They play an active role in the sustainability of air and water quality by improving the quality of life (Figure 6). These networks, which are also considered as green infrastructure systems, have emerged from the idea of benefiting people by creating connections between parks and green areas. It keeps these systems together, provides communication between regions and operates the network system. They are areas where mobility is very intense and there is a continuous active flow (McQueen & McMahon, 2003). According to McQueen and McMahon (2003), urban green networks provide a skeleton for conservation and development, planning and design processes occur before development plans, connections are key components, they should be multi-functional at different scales, they should be made in line with land use planning theories and practices, and they are a public investment.

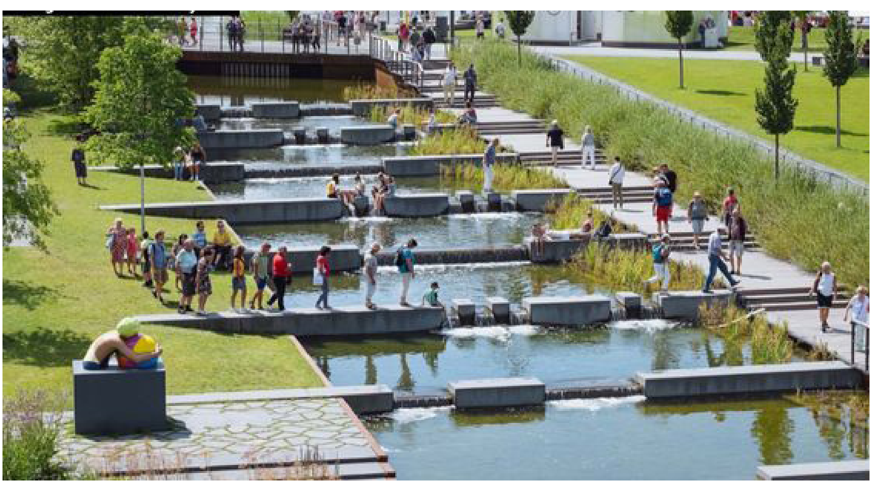

Figure 6. Urban Green Infrastructure Systems (Url- 10;Url-11)

Urban green networks (Figure 7) form a green infrastructure system. It is a formation that allows to fulfil human needs in the natural system. By providing a connected and integrated structure that supports urban functions without harming the atmosphere and water availability, it ensures that requirements such as: bicycle paths, green free paths, natural drainage filter and tree canopy cover are located throughout the system. The creation of green corridors ensures the interaction of active and passive areas, and the creation of a multifunctional structure ensures the optimum balance of natural and artificial relationships and thus the interconnection of all areas. Green corridors; clean air, clean water, soil protection, erosion prevention, proper use of rainwater, preventing flood and flood risk, reducing carbon emissions, preventing heat island formation in cities, supporting biodiversity, creating ecological corridors, providing habitat. It is an interconnected green space system that benefits people by preserving the value and function of the natural ecosystem, and this interconnectedness is the core areas.

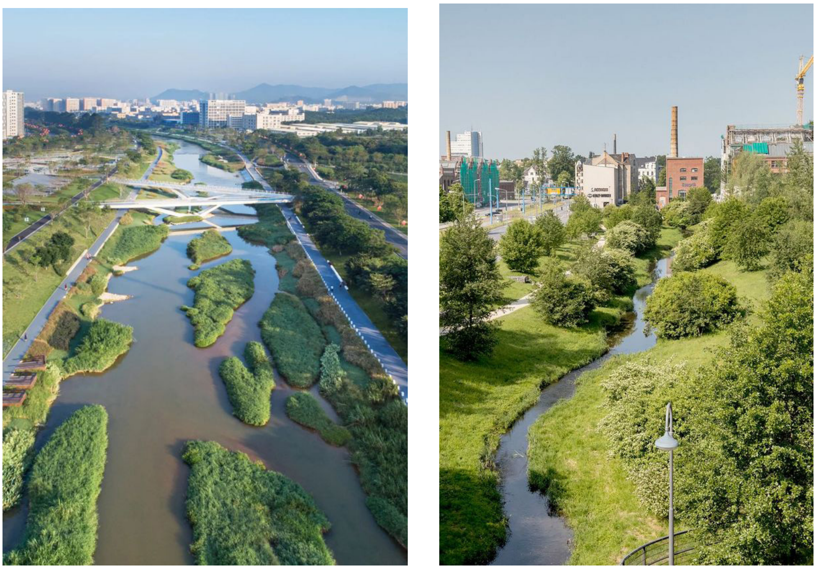

Figure 7. Urban Green Infrastructure Systems (Url- 12;Url-13)

The concept forms a basis for eco-city design objectives in countries where the planning tradition is established; it addresses protected areas (wetlands, water channels, wildlife corridors, etc.), areas worthy of protection (forests, absolute agricultural areas, etc.) and other open green areas (parks, green roads, green corridors, etc.) within a certain systematic framework (Benedict & McMahon 2006). Green networks in urban areas also contribute to important ecosystem services.

- It provides ecosystem functions and components and food supply. It provides food for urban people with vegetables produced in urban parcels and areas around the city.
- It has the effect of regulating water flow and alleviating surface runoff. It creates a permeable structure with soil and vegetation cover or percolation of water during prolonged rainfall. It prevents surface runoff caused by excessive rainfall in the city.
- It regulates the surface temperature in cities. Trees, vegetated surfaces, green roofs and other urban vegetation provide shade and block moisture and wind.
- They have the effect of reducing noise in cities. Vegetation barriers, especially thick vegetation, absorb sound waves.
- Binding pollutants with stems, roots and leaves of urban vegetation cleans and removes pollutants from the air.
- It has an environmental improvement effect. Storm, flood and

wave buffering with vegetation barriers, they provide heat absorption during severe heat waves.

- Increasing tourism and destination opportunities (diversification of recreation opportunities and increasing capacity). Ensuring education and sustainability (sustainability of ecosystem services),
- It regulates the climate in cities and enables carbon capture and storage (Tülek & Ersoy Mirici, 2019).

2. CONCLUSIONS

Increasing urbanisation and industrialisation process has made it compulsory for cities to develop as green systems in harmony with nature. In order to increase the quality of urban life, the creation of green networks throughout the city has been an important factor in terms of sustainability. The creation of green networks throughout the city to increase the quality of urban life is an important opportunity for sustainability.

The creation of a continuous and holistic green infrastructure in urban areas should establish connections between green areas in the city based on data on green areas. These connections form green networks in cities. In order to create green and open space continuities and thus to improve ecosystem services, it is necessary to define planning and design tools that will be effective in the regional-urban-urban sequence. Defined urban green networks also have different functions in cities. The most important element that connects the spots in green networks with each other is corridors. Natural corridors and river corridors are very important in ensuring connectivity and continuity of natural vegetation.

It is possible to achieve a more sustainable urban ecology when green infrastructure studies are integrated into urban planning levels. Green infrastructure is an approach that envisages the collaboration of various disciplines at different scales and brings original solutions by working with current urban planning and design ideas. Green infrastructure, if properly planned and prioritised, can provide a wide range of benefits for both individuals and nature. For this reason, planning and design principles based on ecological approach should be established from upper to lower scales in the urban planning process. This approach reveals ecological, economic and socio-cultural services. In addition to providing positive contributions to the ecosystem, green infrastructure systems also provide high visual quality spaces as landscape elements.

One of the most important positive effects of green infrastructure systems is their impact on water management. Green networks in cities maintain the water cycle by creating permeable surfaces. Water passes through permeable surfaces instead of impermeable surfaces and mixes with groundwater. In addition, water management is provided with green roofs, rain gardens, permeable pavements, rainwater retention systems, rainwater storage tanks (rain barrels and cisterns) and wetlands created in green networks. Green infrastructure systems can provide solutions to rainwater runoff and the environmental problems caused by impervious areas that are increasing day by day as a result of excessive urbanisation and dense construction.

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EXPERIENCE OF A STREET REHABILITATION PROJECT IN HISTORICAL TEXTURE: THE EXAMPLE OF LADİK HÖYÜK

Zafer KUYRUKÇU[1]

1 Dr. Öğr. Üyesi, Konya Teknik Üniversitesi, Mimarlık ve Tasarım Fakültesi, Mimarlık Bölümü, ORCID: 0000-0001-6454-7484

1. INTRODUCTION

Historical environments have been formed as a result of the integrity of physical, archaeological and artistic values formed by buildings, ruins and open spaces that have survived from the past to the present, as well as social values that include the users of the city. Historical ruins are usually architectural products produced by successive societies and bear witness to the period. Today, historical environments that are subject to change and transformation due to physical obsolescence (aging), rapid and unplanned urbanization, population growth and the influence of technology are undergoing deterioration. Preventing the deterioration of historical environments, protecting the totality of physical and social values that make up these environments, integrating them with daily life, providing new points of attraction to the city, contributing economically to the local, ensuring continuity of use of structures and improving comfort conditions are shown as the main purpose of protecting historical environments (Ahunbay, 2004; Aykaç, 2009; Çelik and Yazgan, 2007; Smith, 2002).

Historical environments are named with the concept of 'site' and protected areas are classified as archaeological, historical, urban and natural sites in the Law on the Protection of Cultural and Natural Assets numbered 2863. According to the Regulation on the Identification and Registration of Immovable Cultural Assets and Sites that Need to be Protected, an archaeological site refers to 'settlements and areas where all kinds of cultural assets that reflect the social, economic and cultural characteristics of the periods in which they lived, the products of ancient civilizations that have reached from the existence of humanity to the present, underground, above ground and underwater'. Within this framework, archaeological sites are divided into three degrees in terms of their importance and the protection and use conditions to be applied in the field. While absolutely no construction is allowed at I-degree archaeological sites, simple repairs of unregistered structures can be made at II-degree archaeological sites. III-degree archaeological sites have been identified as areas where planning can be carried out.

There are different preservation techniques applied to historical environments and structures. Restoration practices are carried out to preserve and repair the originality of historical structures scientifically and technically. Intervention methods and restoration techniques vary depending on the condition of historical structures. The main restoration techniques applied in historical buildings are listed as consolidation, cleaning, integration, sorting, reconstruction, rehabilitation, re-functioning, transportation. Among these restoration techniques, rehabilitation is called interventions that include applications for cleaning, facade cleaning and simple repairs of structures that challenge traditional urban textures, cleaning of structures from non-essential elements (wire, air conditioning, signage, eaves, windows, floor additions, etc.), facade cleaning and simple repairs (Yergün, 2019). It aims to protect historical environments with street rehabilitation, to benefit people living in the area from the comfort of modern life, to increase the aesthetics of the city and to raise the level of conservation awareness among the local population (Çelik and Demirtaş, 2019). In the basic logic of street rehabilitation, the high costs experienced in the individual repair of immovables, which are cultural assets that need to be protected, are shown. For this reason, instead of the singular repair of cultural assets, the idea of the rehabilitation of urban tissues and the streets, which are the main components of these urban tissues, has emerged (Ünver, 2017). "Street rehabilitation projects and implementations" are defined in the law on the Protection of Cultural and Natural Assets 2863 as "relay, restitution, restoration, urban design projects aimed at protecting and documenting immovable cultural assets and other structures on the street along with all elements defining the original street texture in urban protected areas and conservation areas, as well as all kinds of projects and their applications that need to be done in engineering branches". In this study, aims to present the street rehabilitation project carried out to protect the tissue integrity and integrate the historical Mound, which is located within the boundaries of the II-degree archaeological site in the Ladik Neighborhood of Sarayönü District of Konya Province, with modern life. In this direction, the proposals developed for the facade rehabilitation of the street texture of Ladik Höyük and the renovation of urban reinforcement elements have been included. Since Ladik Höyük is located within the boundaries of an II-degree archaeological site, only simple repairs can be made to the immovables. Therefore, the rehabilitation technique has been applied as a protection approach.

2. RESEARCH FINDINGS

2.1. Findings about the Lâdik Neighborhood

Ladik settlement (Figure 1), once known as Laodicea (Combusta), located in the northwest of Konya, about 50 kilometers from the city center, on the Konya-Afyonkarahisar highway, today has the status of a neighborhood connected to the Sarayönu District of Konya. It is located about 7 kilometers south of the district center of Sarayönü (Figure 2). There are Kurşunlu and Ertuğrul neighborhoods as residential areas in the east.

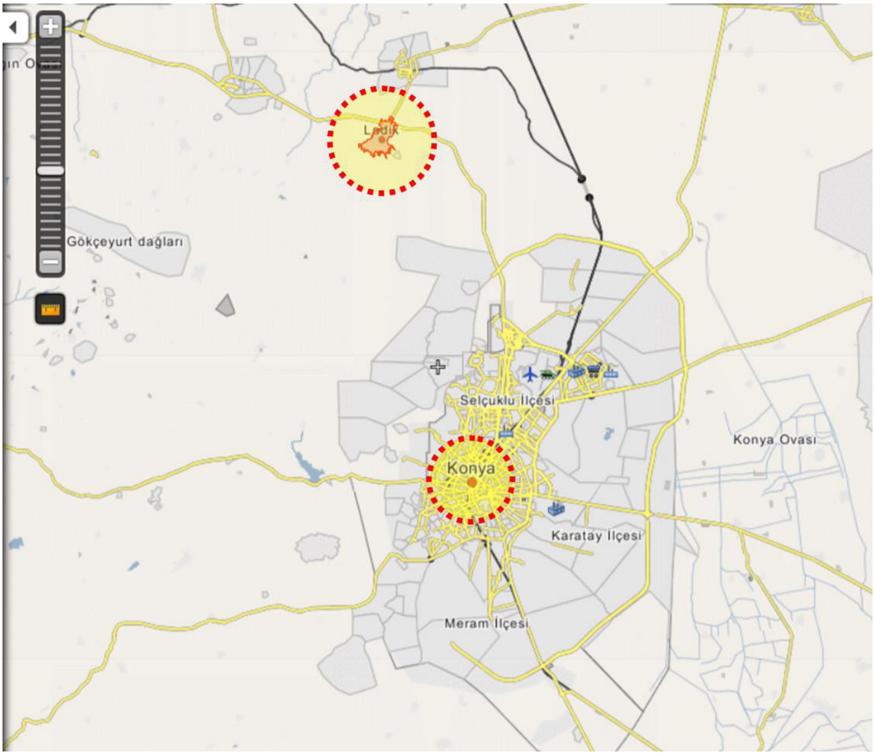

Figure 1. *Geographical location of Ladik (URL-1)*

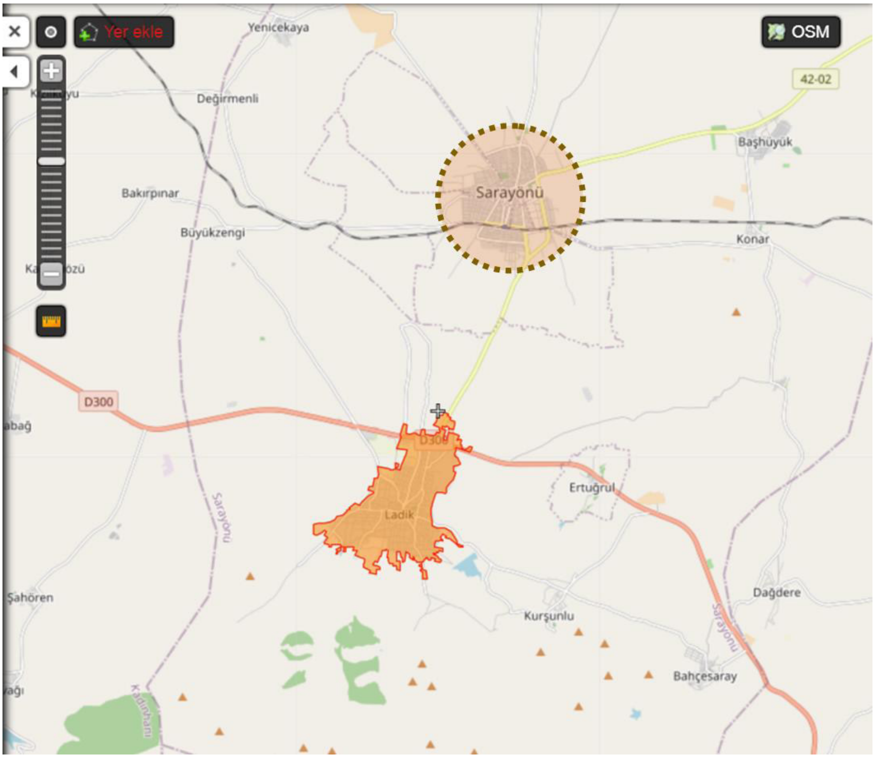

Figure 2. *Ladik and its immediate surroundings (URL-2)*

It is accepted that Lâdik, where there have been settlements since the Chalcolithic Age, was an important center during the Hellenistic and Roman periods. Lâdik, which is estimated to have been founded in the 3rd century BC by the Seleucid Empire in the Hellenistic period as an important tool of the Hellenization policies of Asia (Anatolia), is one of the five cities named Laodicea at the time.

Lâdik and its surroundings have always been of great importance strategically and militarily due to the fact that it was one of the routes that provided connections from the coasts of Western Anatolia starting from the Hellenistic and Roman periods to Cilicia and Syria. In the Hellenistic period, it was turned into a city protected by a garrison, and in the Roman period it became even more important because it formed the link of the eastern military road of the empire. The fact that many Greek and Latin inscriptions have reached from these periods to the present day also proves this. Lâdik, which entered the process of decline during the Byzantine period, came under the domination of the Turks during the Anadolu Selcuklu period. Before the Ottomans dominated Lâdik and its surrounds, Karamanoğulları and Turgutoğulları ruled (Bahar, 2014; Kurt, 2014).

During the Republican period, it was in the status of a village connected to the Kadınhanı District, but it turned into a town in 1959. Although the name ‘Halıcı’ was officially given to Lâdik in the 1960s, this name was not adopted by the local people. In 2012, it was connected to Sarayönü District as a neighborhood. Today, it has the largest population among the 26 neighborhoods that make up the district of Sarayönü. According to the data of 2022, 10.294 of the population of Sarayönü district, which is 27.771, lives in the Lâdik Neighborhood. (TÜİK, 2023).

Carpet making, which once gave its name to the town, formed the most important source of livelihood for the people. Lâdik carpet, which started to become widespread from the 17th century, continued to be produced in a traditional sense until the end of the 20th century (Karpuz, 2012). However with the proliferation of modern carpet factories, the production of hand-woven carpets has suffered greatly, and the number of looms has gradually decreased. Today, the local people mostly make a living depending on agriculture and animal husbandry.

There are small mountains to the east and west of this ancient settlement established at the foot of Laodicea Mountain, which is considered a continuation of the Taurus mountains (Erdemir, 2014). The south is surrounded by mountain ranges, and the north is a plain (Figure 3). Its height from the sea is about 1160 meters. It is located at an altitude of about 100 meters from the district center of Sarayönü. A typical continental climate is observed. Due to the fact that the neighborhood is open to the north wind, the winter months are quite harsh. The settlement is spread over a circular area with a radius of 4 kilometers. The only elevation of the settlement, the terrain of which is quite flat, is Ladik Höyük, located in the center.

Figure 3. *3D view of Ladik (URL-3)*

2.2. Findings Related to the Field of Study

Ladik Höyük, which was selected as the study area, is located in the center of Ladik (Figure 4). It is also called the Hill or Upper Neighborhood. Its history dates back to prehistoric times, and it exhibits the characteristic of being the first settlement of Ladik, where ancient architectural works belonging to the Hellenistic and Roman periods are concentrated (Figure 5). Ladik Höyük is an archaeological site that reflects the historical identity of the settlement, the social, cultural and economic structure, lifestyle and philosophy of past periods. It is located within the boundaries of a second-degree archaeological site. There is a mosque (Ulu Mosque) belonging to the Anatolian Seljuk Period on the mound and immovables used as residences that define socio-cultural life in a traditional architectural style. These structures, which are settled in accordance with the typical Turkish urban settlement tradition, usually have a courtyard or a garden.

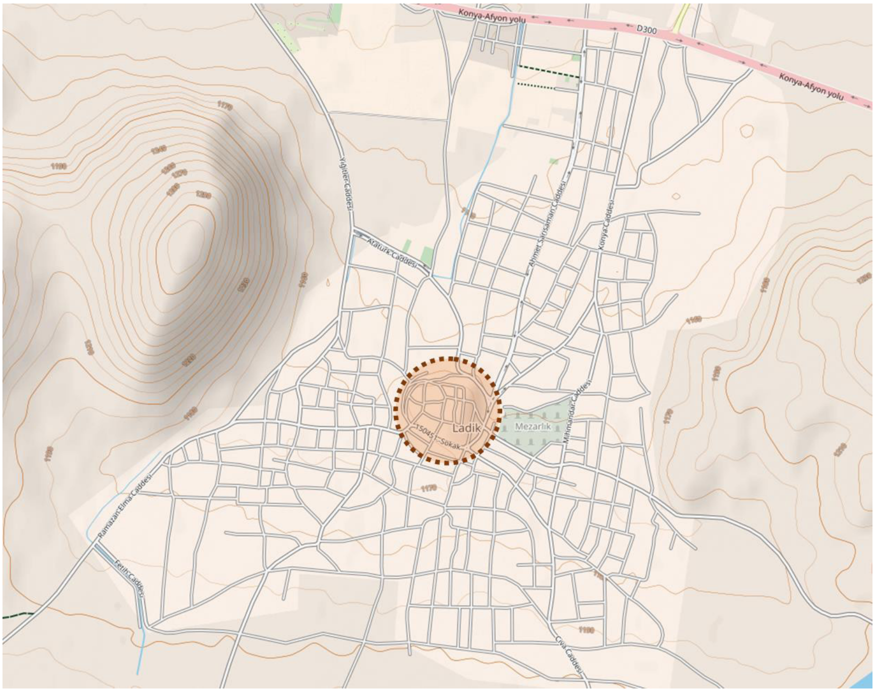

Figure 4. *Urban location of Ladik Höyük (URL-4)*

Figure 5. *General view of Lâdik Höyük*

The street rehabilitation work was carried out in such a way that it will cover a part of the Mound at the first stage, not the whole of it. The streets that provide the connection of the Ulu Mosque, which is located in a location that can be considered the center of the Mound, both with the neighborhood square and with the house of Ahmet Hudai, one of the spiritual values of Konya, have been designated as a working area (Figure 6).

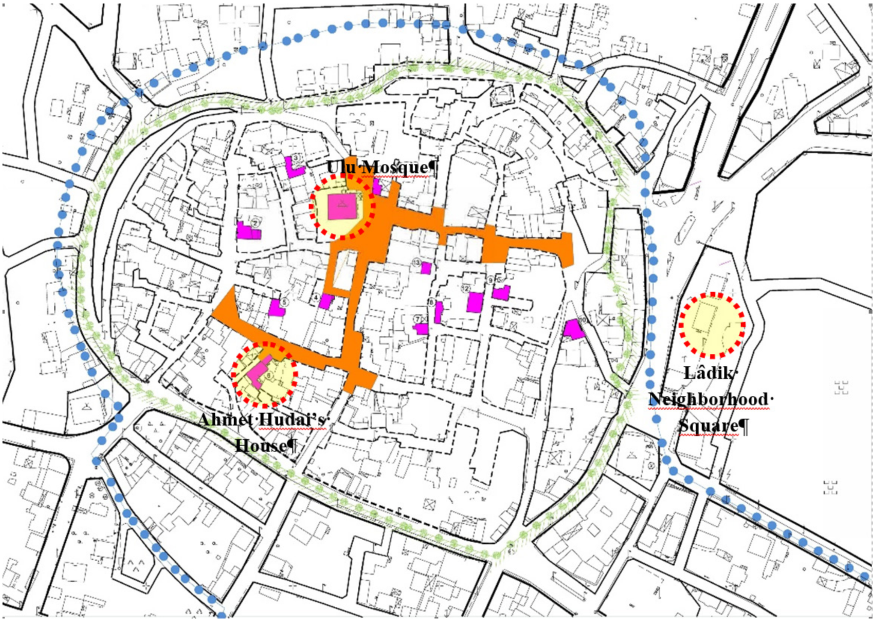

Figure 6. *Street axles designated as a working area*

There are 41 buildings in the area where the study was conducted. The general appearance of the study area and the locations of the structures within it are shown as follows (Figure 7).

Figure 7. *General view of the structures located in the study area*

The construction material of 36 of the total 41 structures located in the project area is adobe, and only 5 of them are reinforced concrete. The reinforced concrete structures are the structures in the parcels numbered 1475, 1476, 1480, 1483 and 1434 located on the island numbered 1177 (Figure 8).

Figure 8. *The positions of the reinforced concrete structures in the area where the study was carried out*

When we look at the general condition of the structures located on the streets subject to the project, it is seen that many of them are quite decrepit, in a state of disrepair and add an unhealthy appearance to the overall texture of the streets. Urban spaces and open spaces, except for the structures located along the streets, give the street undefined and unhealthy views in the same way. It offers a very unhealthy appearance with electricity poles, wire cables, walls that are about to collapse, outdated building facades, neglected roofs and chimneys, rather outdated living units that can be seen in places in open areas, children's playgrounds and green texture that are not qualified along the streets (Table 1). However, in addition to being located in a very important position from an identity point of view, this area also includes the house of Ahmet Hudai of Ladik, which is one of the important triangulations and tourist points of Ladik. The solution to the problems of the project area, which is located in such an important position, both at the architectural and urban design scales in the current situation, will reveal the potential of the area, increase its livability and ensure its sustainability, so that identity values can be transferred to future generations. This will also be a kind of step that can also have economic benefits to the local community.

Table 1. *General view of the structures and urban spaces located within the study area*








2.3. Decisions Made on an Urban and Architectural Scale Related to the Field of Study

Maintenance and repairs have been carried out on the axles determined by the street rehabilitation work in such a way as not to damage the nature of immovable cultural assets, on the faces facing the road that is still being used today, the necessary improvements have been made on the interfaces of the designated structures in accordance with their original forms. During the proposed project process, social impact design was taken into consideration and general decisions were made for public spaces such as the arrangement of street floors on the basis of texture, the design of squares and open spaces.

Design proposals have been developed in which these areas are connected in a way that will not disrupt the physical, social and economic integrity of the Lâdik Neighborhood Square, which is located to the east of the study area, and the streets where the rehabilitation project has been carried out, and even strengthen them further.

Within the scope of the project, the following decisions have been made for the general layout on an urban scale (Figure 9):

- Design of squares and spaces
- Articulation of urban furniture
- Protection of the green tissue
- Design of street floor coverings

Figure 9. *The layout plan and the decisions made on an urban scale*

By analyzing the types of construction of buildings, decisions were made for both adobe and reinforced concrete structures on an architectural scale.

The decisions taken for adobe structures are as follows (Table 2):

- Repair simple facade distortions with adobe plaster and painting the facade white
- Repair of roofs with pantile type tile roof cover
- Renovation of window and door joinery with wooden material
- Renovation of railings with knotted iron grille
- Renovation of rain gutters
- Renovation of roof pediments
- Renovation of chimneys

Table 2. *Decisions made for adobe structures*


Repair of facades with adobe plaster   Repair of roofs with pantile type tiles


Renovation of window and door joinery with wooden material

Renovation of railings with knotted iron grille

Renovation of rain gutters

Renovation of roof pediments

Renovation of chimneys

The decisions taken for reinforced concrete buildings are as follows (Table 2):

- Repair simple facade distortions with plaster and painting the facade white
- Repair of roofs with marseille type tile roof covering and making the roof constructions of structures without a roof using marseille-type tile roof covering
- Renovation of rain gutters
- Renovation of window joinery with pvc material with wooden appearance
- Renovation of door joinery with wooden-looking aluminum material
- Renovation of chimneys

Table 3. *Decisions taken for reinforced concrete structures*

Repair of distortions on facades with plaster

Completion of structures without a roof with marseille-type tiles

Repair and cleaning of chimneys

Renovation of rain gutters

Renovation of window joinery with pvc material with wooden appearance

Renovation of door joinery with wooden-looking aluminum material

In line with the decisions made for both adobe and reinforced concrete structures on an architectural scale, the changes in the existing texture of the streets have been revealed with silhouette drawings (Figures 10 and 11).

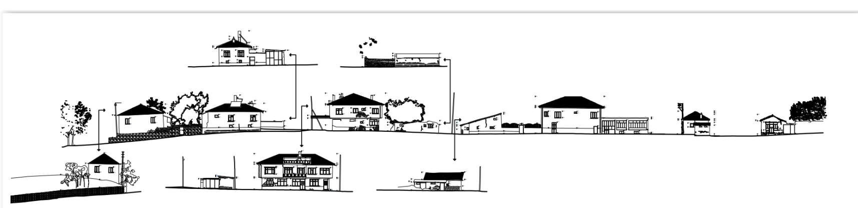

Figure 10. *The current silhouette of the street number 150463*

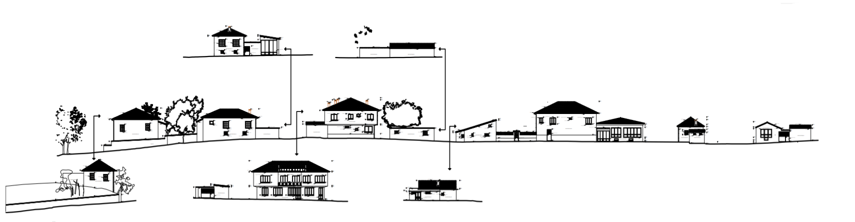

Figure 11. *The proposed silhouette of the street number 150463*

The effect of the simple repairs to be made for the immovables in the work area and the suggestions made for urban accessories in the third dimension have also been tried to be explained by modeling (Table 4).

Table 4. Three-dimensional narratives for the field of work

3. EVALUATION AND CONCLUSION

Historical environments are the expression of a large and important accumulation that reflects the social, cultural and economic structure, lifestyle, philosophy and architecture of past periods. They are vital environments that carry the traces of the past to the present. These environments, especially under the influence of urbanization, population growth and technology, are physically worn out and even face the danger of extinction. Today, undefined open areas and archaeological ruins that have remained in the urban fabric have begun to break away from urban life, despite their inclusion in zoning plans for conservation purposes. If these historical ruins are not integrated with daily life, these areas will continue to be abandoned. The most important way to prevent this condition is to protect, improve and keep the historical tissues alive. One of the methods used to keep historical environments/tissues alive by protecting them is sanitation/facade rehabilitation. Therefore, the street rehabilitation and facade rehabilitation studies carried out / to be carried out in such areas are becoming increasingly important and widespread.

Within this framework, the Lâdik Höyük Street Rehabilitation Project aims to preserve the social/urban and architectural memory of the past and create more livable and usable effects for users of the streets/public spaces located in the relevant area. With this project, the first step has been taken to integrate Lâdik Höyük, which reflects Ladik's urban identity, with daily life and to address it with a holistic conservation approach. It is expected that the street rehabilitation project will be implemented first, and a conservation approach will be implemented to cover the entire Lâdik Höyük at the next stage.

INFORMATION

This study was produced from the project called "Ladik (Loudikeia) Höyüğü 150452, 150454, 150455, 150456, 150459, 150459, 150462 and 150463 numbered Street Rehabilitation Project (*Ladik (Loudikeia) Höyüğü 150452, 150454, 150455, 150456, 150459, 150462 ve 150463 nolu Sokak Sağlıklaştırma Projesi*)", which was carried out through Konya Technical University Faculty of Architecture and Design Circulating Capital, in which the author worked as a researcher.

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SEISMIC ENHANCEMENT THROUGH REPAIR AND RETROFITTING FOR MASONRY STRUCTURES DAMAGED BY THE 2023 KAHRAMANMARAŞ EARTHQUAKES

Serife OZATA[1]

1 **Res. Assist. and Architect (PhD),** Ahi Evran University Faculty of Engineering and Architecture, Department of Architecture, Kirsehir, Türkiye ORCID ID: /0000-0003-1993-7592, serife.ozata@ahievran.edu.tr

Given Turkey's extensive structure of active fault lines and seismic zones, communities inhabiting these areas have coped with earthquake calamities for millennia. Since the inception of the Republic of Türkiye in 1923, the region has been prone to devastating earthquakes, evident in the historical seismic activity. The seismic events that occurred on February 6, 2023, measuring 7.7 and 7.6 magnitudes, with epicenters located in Kahramanmaraş Pazarcık and Elbistan, and another quake event on February 20, 2023, measuring 6.4 (Mw) in Hatay (Fig.1), were highly impactful and destructive disasters in the 21st century. The ongoing effects have resulted in the loss of over 50 thousand lives, leaving hundreds of thousands injured. According to the Ministry of Interior, these seismic events with tens of thousands of aftershocks caused a devastating toll, with a tragic loss of 50,783 lives and injuries sustained by 107,204 individuals (Union of Chambers of Turkish Engineers And Architects (TMMOB), 2023).

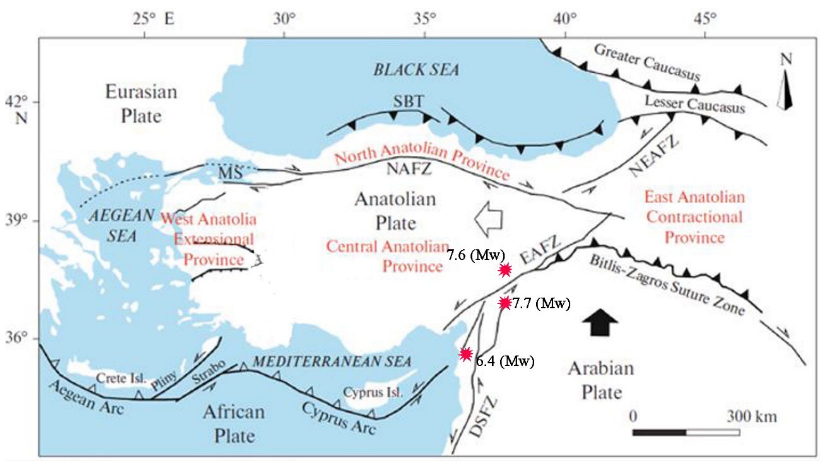


Fig.1. *Active tectonic fault zones and provinces in Türkiye with epicenters of the 2023 Kahramanmaraş and Hatay earthquakes (EAFZ: East Anatolian Fault; DSFZ: Dead Sea Fault Zone; Zone; NEAFZ: Northeast Anatolian Fault Zone; NAFZ: North Anatolian Fault Zone; SBT: Southern Black Sea Thrust (Map adapted from (Kahya et al., 2023)).*

Fig. 2 illustrates the significant impact of earthquakes on Türkiye. The comprehensive timeline spanning 100 years, showcases 13 earthquakes exceeding a magnitude of 7.0. It also reveals a considerable number of earthquakes falling within the Magnitude (Mw) 6.0-7.0 range, with the 15 most severe quake-related incidents, each resulting in more than 50 casualties (Bogazici University Kandilli Observatory, 2023) highlighted in Fig. 2. It underscores the persistent seismicity in Türkiye, with the above-mentioned recent catastrophic earthquakes of Kahramanmaraş and Hatay serving as tragic examples. Examining the map in Fig.1 and the timeline in Fig.2 highlights the certainty of ongoing seismic activity with high magnitudes in Türkiye. Regrettably, the primary reason behind the significant casualties is the absence of earthquake-resistant construction in buildings. As a result of these earthquakes, millions of buildings endured varying degrees of damage, ranging from severe to moderate and light, with some collapsing entirely.

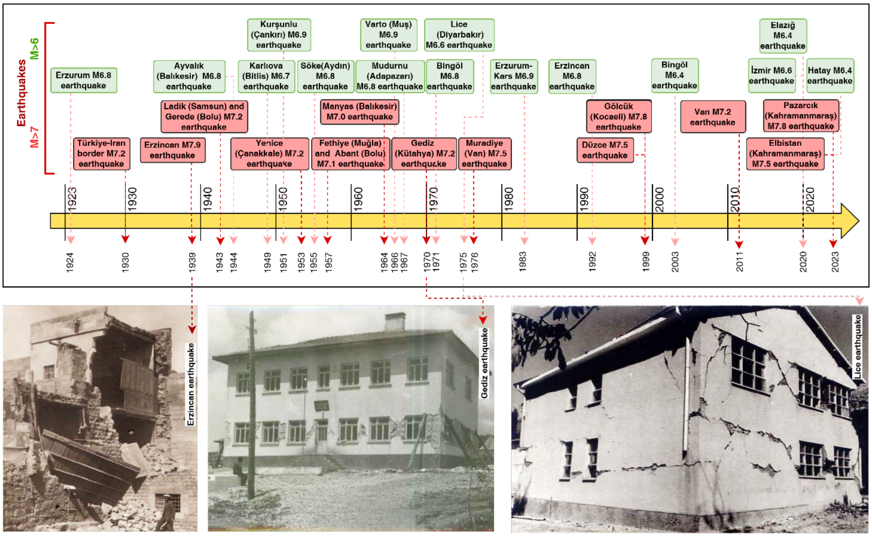


Figure 2. *Chronology of earthquakes (magnitude > 6) since the establishment of Türkiye, including instances of damaged masonry structures*[1]

In Türkiye, there are over 11 million buildings (Tunc, 2021), with approximately 24% (2,618,697) located in 11 earthquake-affected cities (Ministry of Interior, 2023). Following recent earthquakes, millions of buildings suffered various degrees of damage in these provinces. According to the damage assessment studies of the Ministry of Environment, Climate Change, and Urbanization, around 41% of buildings in these provinces exhibited damage (SBO, 2023). Among inspected buildings, 10.5% were severely damaged, 3.2% moderately damaged, and 25.2% slightly damaged (SBO, 2023). Due to the prevalence of buildings with RC structural systems, extensive studies have been conducted to assess the damages caused by the earthquake on RC structures (Ivanov & Chow, 2023; Karakale et al., 2023; Ozturk et al., 2023).

According to data collected from different sources, (Ministry of Interior, 2023; Özer Ay & Eroğlu Azak, 2021; Strategy and Budget Office (SBO), 2023) the structural composition of buildings in Türkiye shifted from predominantly masonry in the early 20th century to a reversal in the

1 Erzincan earthquake photo taken from (Avni Öztopcu, 2023) and Gediz and Lice earthquake photos obtained from (Bayülke, 2011).

post-1980s era. Notably, after 2000, the production of RC frame buildings surpassed 90%, effectively doubling the total number of pre-2000 RC frame structures. In provinces affected by earthquakes, the choice of structural systems mirrors national trends, with RC Frame emerging as the predominant and widely adopted construction method.

The prevalence of masonry buildings, while constituting a relatively modest percentage (5.7% in Türkiye, 3.5% in earthquake-affected cities), amounts to over 90 thousand structures, particularly concentrated in regions impacted by seismic activity. Moreover, Türkiye hosts over 120,000 culturally and historically significant buildings (Ministry of Culture and Tourism, 2022), mainly constructed with masonry, highlighting the crucial need for their conservation.

Progress in building technology and materials, along with growing apprehensions about the seismic resilience of masonry constructions, the rising desire for tall structures, and the perception that existing building codes and regulations may not sufficiently address the safety of masonry constructions, are essential factors influencing the ongoing transformation of construction practices and structural forms. Notwithstanding these challenges, the construction of earthquake-resistant and resilient masonry structures is viable. The validation for this claim is found in the presence of more than 120,000 historic masonry buildings in Türkiye, showcasing resilience and warranting preservation. When considering masonry structures globally, these numbers extend into the millions(Ozata, 2023). Thus, preserving and transmitting the intricate details of existing masonry structures becomes crucial to mitigate the aforementioned factors that adversely impact masonry construction.

Despite the advantages of masonry structures, including historical significance, low maintenance, local availability, effective sound insulation, and high thermal mass, their significance has diminished due to unconscious construction techniques and the breakdown of the master-apprentice relationship. Hence, ensuring the reliable continuation of this building type involves identifying mistakes in earthquake-damaged masonry structures, avoiding the repetition of these failures, and proposing suitable repair and retrofit samples for use in similarly damaged structures.

Sharing insights from this study on masonry damage and its root causes is essential to prevent recurring errors in future masonry constructions and implement necessary precautions. The study also provides fundamental repair and strengthening recommendations for restoring and addressing similar challenges in the construction or restoration of masonry structures after seismic incidents.

In the literature, several comprehensive theses, publications (Arun, 2005; Bayülke, 2011; Garcia-Ramonda, 2020; Karakuş, 2012; Shrestha, 2016) and guidelines (Chidiac & Foo, 2017; Government of Nepal National Reconstruction Authority, 2021) have documented various repair and retrofit techniques applied to masonry buildings. These studies often focus on specific case buildings, providing detailed insights into the strategies employed. After the February 6 Kahramanmaraş earthquake, several studies in the literature have investigated the impact of these quakes on masonry structures. For instance, Işık et al. (2023) examined seismic failure modes in specific masonry structures. While Kahya et al. (2023) worked on the damages of a masonry monumental building in Hatay, Mercimek (2023)the failure modes of masonry structures after the earthquakes (Mw 7.7 and 7.6 and Onat et al. (2023)explored earthquake performance evaluations of masonry minarets and mosques, respectively.

Building upon existing research, this study adopts a dual approach. Firstly, it succinctly introduces repair and retrofit techniques for damaged masonry structures except for those applied for damage caused by building foundations and soil conditions. Subsequently, it explores various damage types observed in masonry buildings across different provinces. The damage types under scrutiny encompass a range of issues, including:

- In-plane damage
- Out-of-plane damage
- Wall delamination
- Connection damages
  - Roof-to-wall connection
  - Slab-to-wall connection
  - Wall-to-wall connection
- Floor collapse

The selection of buildings for this study was based on their damage regardless of their place in earthquake-affected zones. The study encompassed various provinces without specific emphasis on a particular region or building use. The rationale behind this approach is that a well-designed masonry structural system should perform as expected in earthquakes, regardless of its function or location. Considering the seismic vulnerability in many regions of Türkiye, the objective is to share insights into the damage types observed in masonry structures affected by an earthquake with significant horizontal and vertical accelerations. This information aims to contribute to reducing the likelihood of recurring errors in future masonry constructions and facilitating the implementation of necessary precautions.

The investigation aims to uncover the root causes of these damages and propose essential repair and strengthening interventions for preventive measures.

1. Repair and Strengthening Techniques For Masonry Structures

Similar to any structure, masonry buildings can undergo damage over time, whether caused by human activities or natural disasters such as earthquakes. Despite being a construction type with a long history spanning thousands of years, its prominence in contemporary architecture has diminished, particularly after 2000, for the reasons mentioned earlier. Nevertheless, like any other architectural style, masonry structures possess distinctive details and behaviours, and preserving them with these characteristics holds significant value in maintaining both the tangible and intangible contributions these buildings make to society. To achieve this, a comprehensive examination of the building, considering aspects like material, strength, durability, and form, is necessary. Interventions, typically in the form of basic repairs or retrofits, become essential. Some applications may even fall into both categories, depending on their implementation methods.

In the realm of damaged structures initiated by earthquake-induced forces, the differentiation between "repair" and "strengthening" centers on their respective seismic resistance outcomes. "Repair" entails post-earthquake restoration without elevating seismic resistance beyond the pre-earthquake state. Conversely, "strengthening", "retrofitting" or in other words "seismic upgrading" involves interventions aimed at improving seismic resistance by augmenting strength (Tomazevic, 1999). The choice between repairing or strengthening a building is contingent on its seismic resistance; if damage aligns with design predictions, repair suffices, but if damage exceeds expectations, strengthening becomes imperative. In the latter scenario, strengthening encompasses both the repair of damaged elements and the enhancement of the overall structural system to achieve the anticipated seismic resistance. Fig. 3 illustrates the repair and retrofitting techniques applicable to damaged masonry structures. Since interventions related to damages caused by soil conditions and foundation-based issues are beyond the study's scope, they are not addressed in the presented methods.

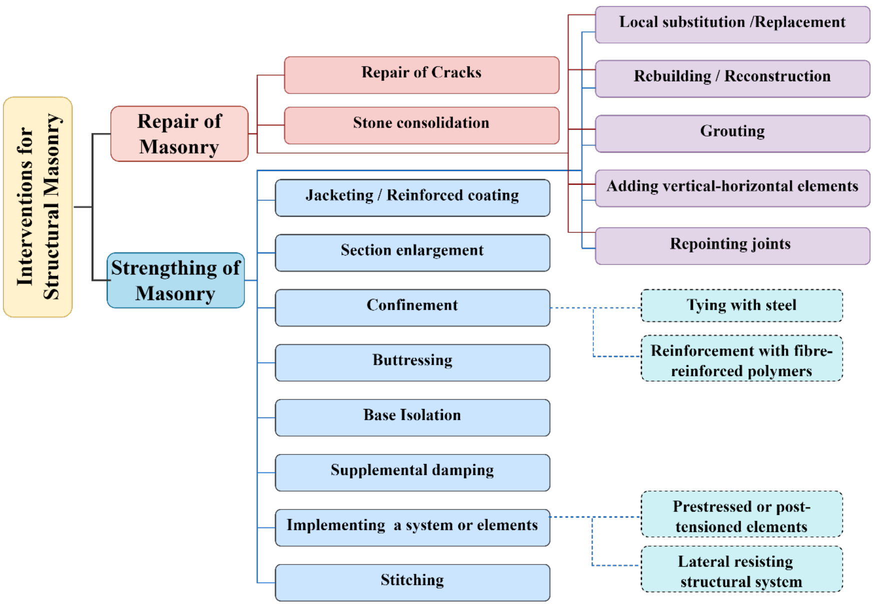


Figure 3. *Repair and retrofitting methods applicable to masonry structures*

It is noteworthy to mention that the design of intervention either retrofit or repair should prioritize minimal impact on the original structure and its surroundings, preserving distinctive qualities without destruction. Additionally, measures taken should be reversible, enabling removal or replacement with more suitable methods as new knowledge emerges, ensuring adaptability. Compatibility, particularly in terms of materials used, must be thoroughly assessed, considering both short-term and long-term effects to prevent undesirable consequences and maintain harmony with existing materials.

The following briefly outlines the contexts of the methods specified in Fig.3:

Considering these intervention criteria, the methods that can be applied in masonry structures as shared in Fig. 3 are as follows:

- Repair of Cracks: This method refers to the process of addressing and remedying cracks that may have developed in brick, stone, or other masonry elements of a structure. This repair work is undertaken to restore the integrity, stability, and aesthetics of the masonry, as well as to prevent further deterioration. Compatible injection grouts and epoxy are ideal for hairline fractures, while mortars are recommended for larger cracks (Tomazevic, 1999). Stitching is employed for cracks that are too wide for standard mortar application.
- Stone consolidation: The goal of this technique is to enhance the cohesion of the stone material, prevent further decay, and ensure the long-term structural integrity and durability of the stone. The method

involves the application of consolidating agents, such as consolidants or adhesives, to the stone substrate (Chidiac & Foo, 2017).

The following methods can serve as interventions for either repair or retrofit, contingent on the specific context and purpose of their application.

- Local substitution /Replacement: For localized damaged areas in masonry, a cost-efficient preservation replacement method involves systematically removing and replacing small, deteriorated sections with new ones that closely match the original material's properties, ensuring the structural integrity of the overall structure. A key benefit of this technique is its reversibility; the masonry can be dismantled and re-laid, allowing for potential future repairs.
- Rebuilding / Reconstruction: This technique involves dismantling and replacing relatively large damaged sections of a masonry structure, ensuring restoration by using current or new materials that closely match the original ones.
- Grouting: Grout injection in masonry is a process of filling cracks or voids in the structure with a fluid mixture, known as grout, to enhance structural stability and mechanical strength, address damage, and ensure the cohesion of the masonry elements. Grouting stands out as a prevalent technique for repairing and preserving historical structures or addressing cracks in architectural elements (Dinç-Şengönül et al., 2023).
- Adding vertical-horizontal elements: Wall deformation, as evidenced by concentrated cracks above and below windows, can be remedied by implementing horizontal elements at the floor level and vertical beams around the window openings to correct the overall wall behaviour.
- Repointing joints: Improving a wall's resistance to vertical and lateral loading is achievable by replacing poor-quality mortar with significantly better mortar in areas where bed-joints are relatively level and units are in good condition. Repointing can be accomplished using specialized mortars, or reinforced elements can be employed in this method (Karakuş, 2012).

The following methods are employed to strengthen masonry structures, specifically for seismic upgrading purposes.

- Jacketing / Reinforced coating: This technique entails applying reinforced plaster or mortar to one or two surfaces of a wall. This method is employed to address specific areas requiring improvement, such as the mitigation of cracks, and can encompass either the entire wall surface or targeted sections. The plaster material commonly comprises concrete with appropriately sized aggregates and incorporates additives designed to prevent creep and enhance adhesion to the masonry surface (Chidiac & Foo, 2017). This approach is utilized for upgrading masonry structures, offering a solution that combines durability and structural enhancement. Fig. 4 displays a vault featuring jacketing, with a visible masonry wall that has a reinforced coating. Careful consideration is essential when employing jacketing techniques, as improper application may restrict the natural behaviour of the masonry structure. In such cases, this method has the potential to cause significant damage, especially during seismic events like earthquakes. Thorough evaluation and adherence to engineering standards are crucial to ensure the effectiveness and safety of this approach.

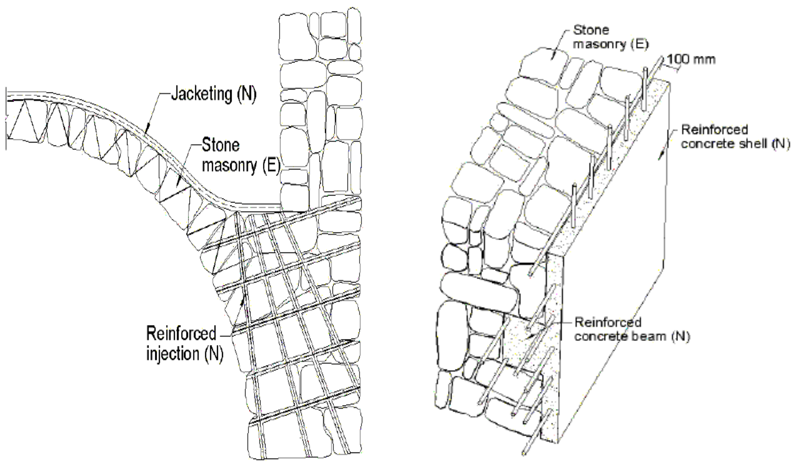


Figure 4. *A masonry vault with jacketing, and a masonry with reinforced coating (Chidiac & Foo, 2017).*

- Section enlargement: This practice involves expanding certain sections, such as walls or pillars, to enhance load-bearing capacity, improve stability, or meet structural requirements.
- Confinement: Retrofitting by confinement in masonry serves a multifaceted purpose, aiming to balance the horizontal thrust of the walls as well as, the horizontal thrust of arches and vaults. Simultaneously, it strives to enhance the bond between the walls and structural components. By strategically addressing these aspects, this retrofitting technique aims to bolster the overall stability, structural integrity, and seismic resistance of masonry constructions. The approach encompasses two key aspects highlighted in the subtitle: “Tying with steel” and “reinforcement with fiber-reinforced polymers”.

Tying with steel: Achieving robust wall connections involves strategically placing steel tie bars on both sides of all structural walls across various floor levels. In instances where buildings have substantial distances between structural walls, the use of diagonal ties anchored at corners and mid-spans, discreetly integrated within wooden floors, becomes necessary to mitigate excessive out-of-plane vibration (Tomazevic, 1999).

Reinforcement with fibre-reinforced polymers: Among various proposals for strengthening techniques involving composite materials, Fiber Reinforced Polymers (FRP), predominantly composed of carbon, glass, and aramid fibers, are extensively utilized. Their widespread adoption is attributed to their high tensile strength, lightweight nature, ease of installation, and resistance to corrosion (Garcia-Ramonda, 2020).

- Buttressing: Adding external buttresses or supports to provide additional lateral support to a wall or structure defines this method. It is used to enhance stability and prevent the risk of collapse, typically employed when existing walls need reinforcement due to factors such as structural weaknesses or the application of additional loads. The application of flying buttresses is a technique developed to prevent the inward closing of outer walls.
- Base Isolation: This is a non-conventional technique that employs specialized bearings comprising steel and rubber layers. These bearings decouple a structure from horizontal ground motion during earthquakes while supporting vertical weight. By elongating the structure's natural period of vibration, base isolation effectively diminishes the transmission of energy, contributing to enhanced seismic resilience (Chidiac & Foo, 2017). Applying this technique to masonry structures becomes challenging since the foundations lack homogeneity.
- Supplemental damping: Mechanical energy dissipation systems, utilizing devices such as eccentrically braced frames, are employed to dampen earthquake-induced shaking in masonry structures. In the conventional eccentrically braced frame system, vertical steel frame diagonals are intentionally offset, and horizontal members are designed to yield under seismic forces (Chidiac & Foo, 2017).
- Implementing a system or elements: An alternative method for enhancing structural capacity involves minimizing potential damage by incorporating a secondary resisting structural system or prestressed or post-tensioned elements.

Prestressed or post-tensioned elements: Due to the low tensile and shear strength of masonry structures, additional efforts are needed to minimize tensile forces. In cases where a certain level of tensile strength is necessary for equilibrium, external connections, often employing prestressed or post-tensioned steel reinforcing bars, are utilized (Fig. 5). Protection against corrosion is crucial for the durability of these tension members.

Lateral resisting structural system: Steel bracings and steel or reinforced concrete (RC) systems are viable options for reinforcing and enhancing the structural integrity of a building. The inclusion frames prevent the collapse of the whole system. Fig. 5 illustrates the plan and details of a masonry tower where both methods are concurrently applied to strengthen out-of-plane stability.

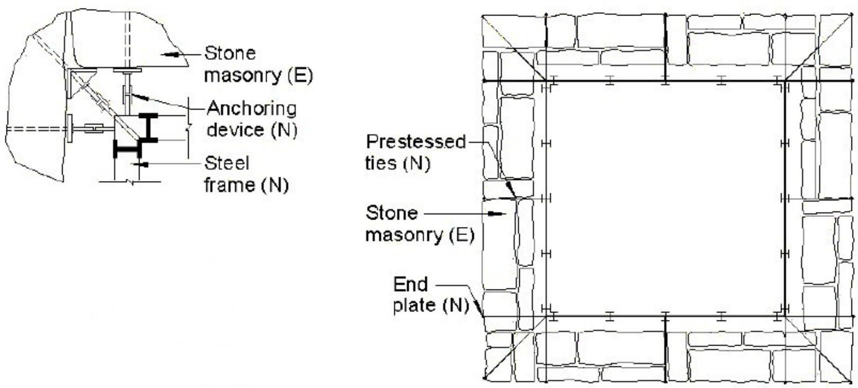


Figure 5. *The plan and details of a masonry tower, featuring the incorporation of a steel frame and prestressed ties (Chidiac & Foo, 2017).*

- Stitching: The purpose of this method in masonry is to address and reinforce structural elements that have experienced cracking or separation to restore the overall stability and integrity of the structure. The technique involves embedding iron and stainless steel elements in lead to join separated materials by a crack within the wall. This process should be executed on both sides of the wall.

2. Post-Earthquake Assessment of Masonry Buildings

Masonry buildings, a longstanding structural practice in Türkiye housing construction, have roots spanning centuries. According to Özer Ay and Eroğlu Azak (Özer Ay & Eroğlu Azak, 2021), the majority of them constructed before 1980, adhered to the traditional approach of unreinforced masonry construction (URM). The evolution of masonry material usage for building construction reflects economic constraints and advancements in manufacturing technology. Traditionally, older structures utilized materials such as adobe, sun-dried bricks, or stone (Fig. 6a). In contemporary Türkiye, masonry structural systems commonly include aerated concrete blocks, fired bricks and hollow concrete blocks. Notably, the majority of masonry structures in earthquake-affected areas are one or two stories tall (Fig. 6a-6b). Instances of three or more-story masonry buildings are infrequent, and when present, they are typically located in suburban areas or historical centers of cities (Fig. 6c). In earthquake-affected cities, the prevalent configuration for masonry structures is one or two stories. Infrequently encountered are masonry buildings with three or more stories, typically situated in suburban areas of cities or within historical centers.

a. b. c.

Figure 6. a. *A damaged masonry 2-floor village house in Nizip, Gaziantep* **b.** *Slightly damaged masonry house in the city center of Elbistan, Kahramanmaraş* **c.** *Extensive partial collapse of a masonry 4-floor building in Antakya, Hatay city center.*

In rural areas, masonry found widespread use in residential structures and ancillary buildings like garages, warehouses and barns. Many of these masonry constructions, deviating from established construction standards and exhibiting irregularities, suffered considerable damage, while others remained relatively resilient (Fig. 6b). Notably, some unreinforced masonry (URM) structures showcased inadequate attachments of structural elements, leading to specific instances of collapse (Fig. 6c).

2.1. Observed Damages on Masonry Structural System

The subsequent sections delineate five distinct types of damage observed in masonry structures following the earthquake sequences in Kahramanmaraş and Hatay.

- In-plane damage
- Out-of-plane damage
- Wall delamination
- Connection damages
    - Roof-to-wall connection
    - Slab-to-wall connection
    - Wall-to-wall connection

- Floor collapse

2.1.1. In-plane Damages

This form of damage encompasses cracking, deformations or failure predominantly oriented parallel to the face of the wall. Structural impairments transpire within the plane of the wall or structure, usually attributed to lateral forces like seismic sequences. Observable manifestations include diagonal cracks, spalling, or distortion of masonry elements occurring in the same plane as the lateral force.

The characteristics of diagonal tensile cracks vary based on factors such as the location and dimensions of door and window openings in the wall plane, the height and length of the wall, the structural solidity, the proximity of the building to the earthquake epicenter, and the ground conditions. Diagonal shear cracks, originating at the window edges and extending towards the interior-exterior wall joints, are evident in this structure (Fig.7).

The intensity of damage, typically expected to be more pronounced on the ground floor, is concentrated on the 1st floor in this case (Fig. 7). This anomaly is attributed to the relatively small openings on the ground floor. Stress accumulation at the edges of openings often results in initial earthquake-induced damages observed primarily at the corners of windows or doors, as depicted in Fig. 7. In seismic events, structures experience forces in both principal directions. Thus, the image of the building's interior illustrates this with the separation of the outer wall. Separation has been initiated in the wall subject to in-plane shear stresses. If the lateral force had continued, out-of-plane damage would likely have established in the wall, rather than in-plane.

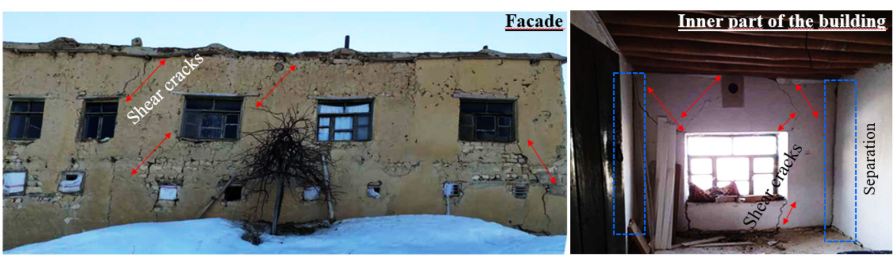


Figure 7. *Shear cracks within the plane of masonry walls, coupled with separation.*

Potentially applicable interventions: The included methods are repairing cracks, employing the contemporary grout injection method, stitching at specific points (Fig.8a) and incorporating wooden vertical and horizontal elements as an example application shared in Fig. 8a and 8b. For retrofitting, options like fiber-reinforced confinements or steel supplemental damping systems are available; however, implementing such systems may incur significant costs and compromise the overall authenticity of the adobe masonry structure.

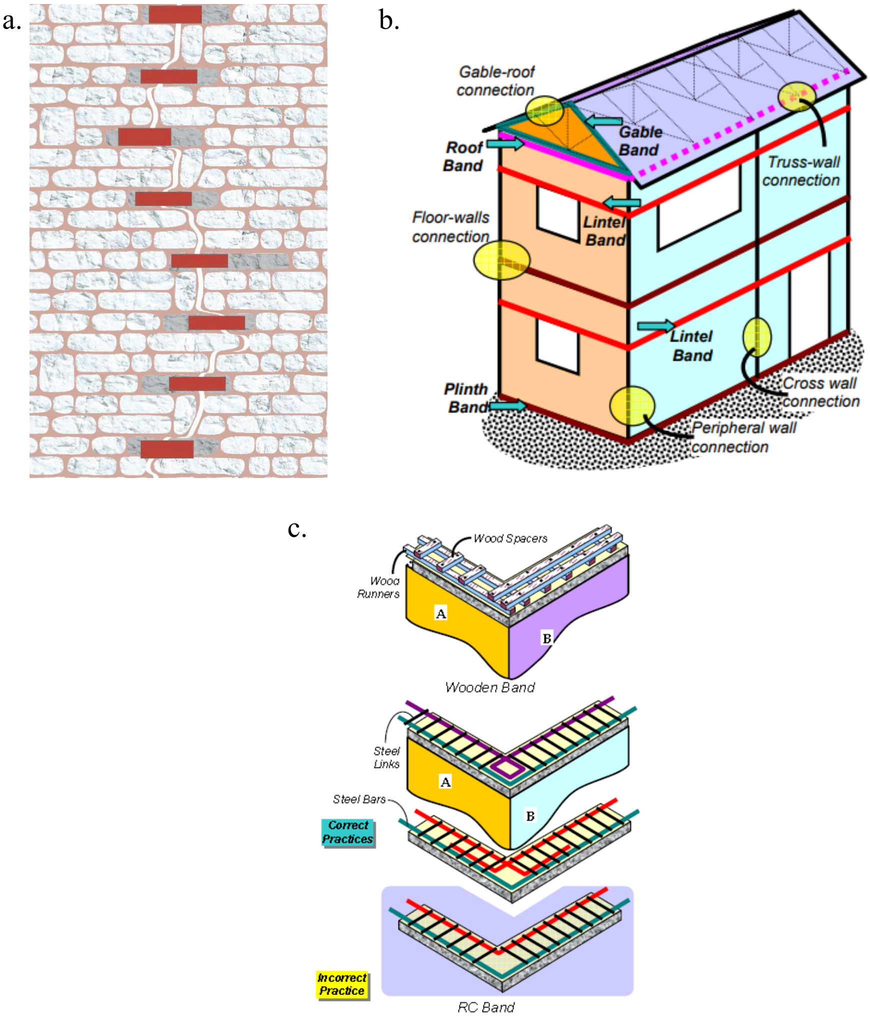


Figure 8. *a. Stitching sample on stone masonry (Government of Nepal National Reconstruction Authority, 2021) b. Potential horizontal bands places (Murty, 2015) c. Wood and RC horizontal bands applications (Murty, 2015)*

2.1.2. Out-of-plane Damages

This category of damage in masonry structures occurs when deformations or failures transpire perpendicular to the primary plane of a structural element. Such damage is typically induced by lateral forces like seismic actions, and the resulting out-of-plane effects may manifest as tilting, bulging or other displacements perpendicular to the wall's main plane.

A significant portion of the wall seen in Fig. 9a collapsed externally due to out-of-plane behaviour. In-plane shear cracking was observed on the down part of the wall where the wall resistance was sufficient to resist out-of-plane failure. Additionally, severe in-plane damage was evident in the transverse wall (Fig. 9b), which, despite the damage, did not topple because the floor joists extended over it (Fig. 9a). These damages are attributed to factors such as the absence of horizontal bands, a using one-way slab, and weak mortar bonding of the building stones. In another structure initially damaged by in-plane shear cracks (Fig. 9c), vulnerability to out-of-plane vibrations emerged. Subsequently, bulging and tilting occurred with out-of-plane movement.

Figure 9. a. *Partial wall collapse due to out-of-plane failure and in-plane shear cracks* **b.** *Shear cracks on the transverse wall* **c.** *Tilting and bulging of masonry wall due to out-of-plane behaviour*

Potentially applicable interventions: Local substitution or replacement may be employed to replace compromised sections, ensuring structural integrity. Rebuilding or reconstruction is an applicable conventional approach, involving the removal and replacement of the damaged wall components in this case as shown in Fig. 10. Additionally, adding vertical-horizontal elements is another method, reinforcing the wall to resist out-of-plane movement. Confinement with steel ties may be a traditional method for this case to strengthen the existing wall, while supplemental damping, a non-conventional and costly method, introduces dampers to mitigate vibrations and enhance resilience. Each intervention method must be carefully evaluated to determine the most suitable and cost-effective solution for the specific characteristics of the out-of-plane damaged wall.

Figure 10. *Steps of rebuilding a wall with out-of-plane failure (Government of Nepal National Reconstruction Authority, 2021)*

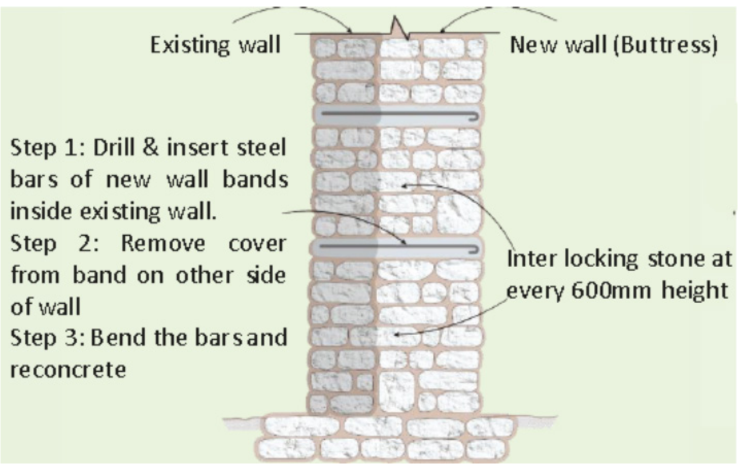
2.1.3. Wall delamination

Within the realm of masonry structures, wall delamination denotes the separation or detachment of layers or sections within a wall, leading to the creation of gaps or spaces. While this type of damage is generally absent in single-leaf, solid walls, it is frequently encountered in double-leaf or cavity walls. Notably, in the case of hollow cavity three-leaf walls, the potential for this damage arises when appropriate horizontal joint elements are not utilized.

In Fig. 11, there is not any trace of in-plane shear damage. Thus, this damage is attributed to the characteristics of masonry construction and mortar. The absence of a horizontal joint element between the layers of the wall is evident, as illustrated in Fig. 11. This lack of interlocking action among the stones further enhances the observed separation.

Figure 11. *The outer rubble stone wall delamination in Malatya*

Potentially applicable interventions: In the process of local substitution and replacement, meticulous attention is required to replace the collapsed segment with compatible stone and masonry materials. When undertaking rebuilding efforts, the incorporation of horizontal elements between the outer and inner layers is essential for ensuring robust connections. Introducing vertical-horizontal elements, as depicted in Fig. 12a, not only limits the impact of partially toppled sections but also showcases a proactive approach to reinforcing structural stability. Reinforced repointing joints offer an effective strategy for upgrading seismic behaviour. The consideration of confinement becomes pertinent, especially if the outer wall is conducive to such an implementation. Furthermore, the option of buttressing (Fig. 12b) proves valuable, particularly for lengthy walls, showcasing the versatility of intervention methods tailored to specific structural needs.



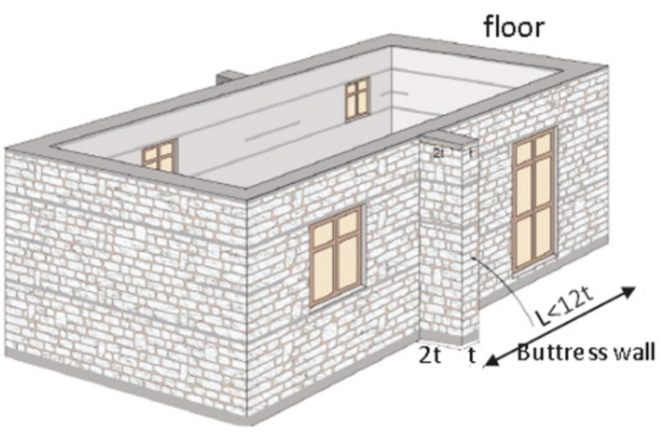


Figure 12. a. *RC horizontal band construction* **b.** *Details of buttressing(Government of Nepal National Reconstruction Authority, 2021)*

2.1.4. Connection damages

In this section, damages associated with the connections between the slab and the wall, as well as those between the roof and the wall will be shared.

2.1.4.1. Slab-to-wall connection damages

This category of damage involves failures at the juncture between supporting walls and the slab, encompassing issues such as detachment, displacement of slab materials, and disruptions in their connections to the walls. The seismic resilience of masonry structures crucially hinges on the diaphragm behaviour of slabs. It is imperative for the diaphragm system to demonstrate uninterrupted continuity along the length of the diaphragm wall. A meticulously connected system not only acts as a cohesive element, restricting in-plane movements of the wall but also bestows a heightened capacity to withstand forces in the plane direction. This intricately interconnected diaphragm plays a pivotal role in fortifying the overall structural integrity against seismic forces.

In Fig. 13a, a significant observation is made concerning the reconstructed slab, which is constructed using reinforced concrete over trapezoidal sheet metal. Critically, it becomes apparent that this rebuilt structure lacks the requisite connection to the existing walls, a detail conspicuously absent in the available information. The absence or incompleteness of connections between the roof/slab and the wall emerges as a primary factor believed to contribute to the complete collapse of the front wall. The inadequacy of this connection prevented the slab from demonstrating diaphragm behaviour, ultimately compromising the structure's seismic performance. Additionally, the placement of this type of slab is implicated in inducing out-of-plane behaviour in the front wall. This analysis presents an original contribution by pinpointing the absence of proper connections as a significant factor in the observed collapse.

In Fig. 13b, the building features a one-way slab with timber joists that were inadequately anchored to the walls, risking their structural integrity. The presence of cracks in the joists indicates relative displacement or shifting between the slab and the wall. Particularly, some timber joists in Fig. 13b have shifted away from the walls. This observation becomes crucial when considering diaphragm behaviour, as the insufficient anchorage and one-way slab organization compromises the ability of the slab to function cohesively with the walls in resisting lateral forces.

a.

b.

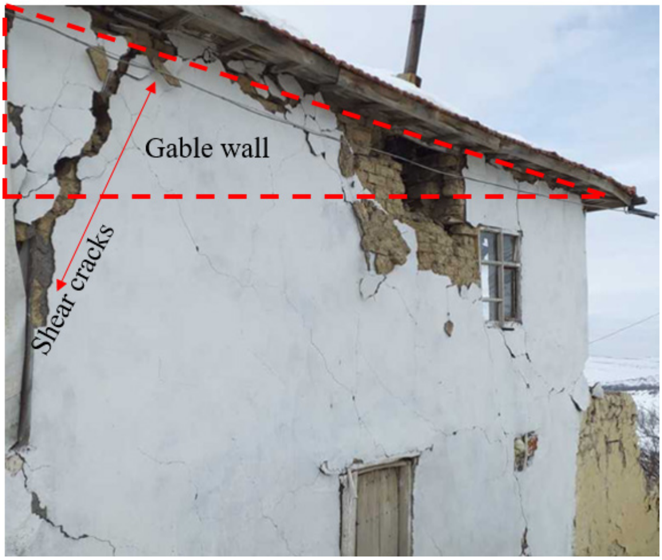
Figure 13. a. *Slab-to-wall connection failure* **b.** *Inappropriate anchorage of timber joist in adobe masonry*

2.1.4.2. Roof-to-wall connection damages

Establishing a robust and continuous connection between supporting walls and the roof is significant. Disengagement and shifting of the roof system along with their connections to the walls involved in this kind of failure.

In the absence of connections with bands at floor level and roof level, gable walls function as cantilever beams, leading to the type of damage illustrated in Fig. 14a. Despite being structurally sufficient for gravity loads, this unbraced and unreinforced gable wall is susceptible to the depicted damage. In Fig. 14b, the discernible movement of timber joists in the roof serves as a catalyst for the initiation of in-plane shear cracks. These cracks, originating from the connection point of the joists, extend across the corner of the opening. A distinctive observation is the absence of a roof band for the joists, which amplifies the vulnerability to such damage.

a.



b.

Figure 14. a. *Out-of-plane failure of gable wall of the roof* **b.** *Movement of timber joists due to lack of roof band*

2.1.4.3. Wall connection damages

Damages resulting from the improper connections between structural walls of masonry are clarified in this section. Inadequate connections between the walls and the adjoining structural components, leading to compromised structural integrity and potential damage.

The masonry wall corners act as stress concentration points, especially during seismic events due to their abrupt geometric changes. These corners, located far from the building's center of mass, are more susceptible to torsional forces induced by earthquakes. Inadequate wall connections, as observed in Fig. 15a, 15b and 15c, have the potential to result in collapses. Lack of two-way slab configuration and inappropriate junction wall details may cause severe damage shown in Fig. 15a. It is important to avoid overlapping joints and vertical joints steer clear of forming a 45-degree angle in the wall's height following insights from Arun (2005). Additionally, configurations of openings, such as the one depicted in Fig. 15c near the corner, could act as a trigger for collapse. Moreover, the ground floor experiences amplified seismic forces in comparison to upper levels, leading to a concentration of damage specifically at the ground floor level such as in Fig. 15c.

a. b. c.

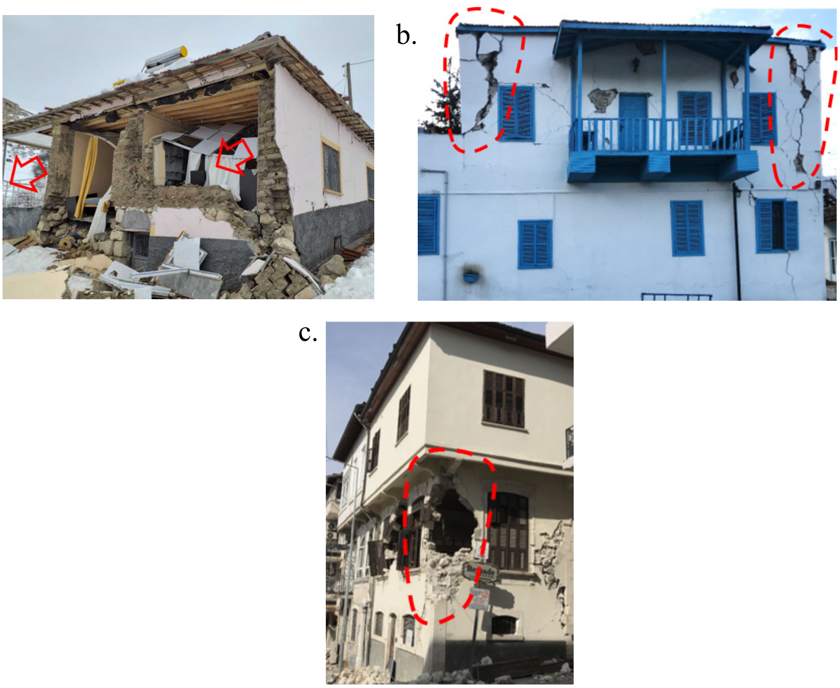
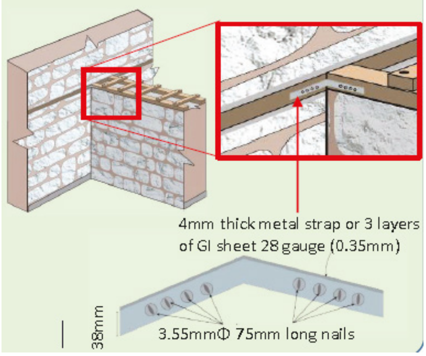


Figure 15. a. *Wall-to-wall connection failure* **b.** *Corner failure along with in-plane damages* **c.***Partial collapse due to lack of corner connection and in-plane damages*

Potentially applicable interventions: Addressing damages between roofs or slabs and wall-to-wall connections requires a strategic and specific intervention approach for each one. Repair of cracks is a fundamental method, aiming to restore the structural integrity by fixing fissures in the affected areas. Local substitution or replacement involves replacing compromised sections with new materials, ensuring resilience. For instance, replacing the gable walls with lightweight materials may contribute to seismic safety. For more extensive damage, rebuilding or reconstruction becomes essential, involving the removal and replacement of damaged elements. Grouting can be employed to fill voids and enhance connections, promoting stability. Adding vertical-horizontal elements reinforces the structure, providing diaphragm behaviour, additional support and preventing further damage. Implementing a comprehensive system or elements involves innovative solutions tailored to the specific context of the damage.

In Fig. 16a, a viable method is depicted for addressing damage to cross-wall connections similar to those observed in Fig. 15a. Fig. 16b illustrates the installation of wooden vertical members from the interior of the wall, serving as a preventive measure against corner failures. Furthermore, Fig. 16c exhibits an extension method applicable to short roof or floor joists. Beyond these examples, various solutions have been devised for connection damages, and the potential for further developments remains open.

a.



b.

c.

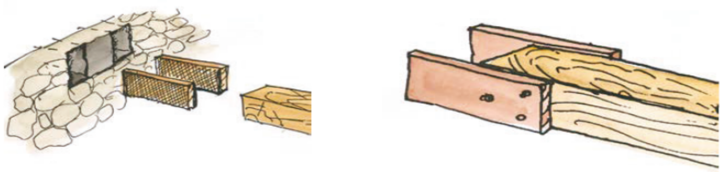


Figure 16. a. *A method for connection of cross walls* **b.** *Installation of wooden vertical member* **c.** *roof and floor joist's extension detail*[2]

2 All figures taken from (Government of Nepal National Reconstruction Authority, 2021)

2.1.5. Floor collapse

The occurrence of floor collapse in a masonry building refers to the structural failure or breakdown of the floor system. Factors such as overloading, inadequate support, or inherent structural weaknesses can result in either partial or complete collapse of the floor structure. The insufficiency of rigidity in establishing slab connections is a common cause leading to damage, including floor failure.

While it is predictably expected to observe more damage on the ground floor than on the upper floors, the building depicted in Fig. 17 presents an unusual case where the upper floor has experienced a complete collapse.

Upon examination of earlier photos of the structure, no external factors indicative of a soft-story mechanism were discerned. However, it is plausible that the removal of inner structural walls on the upper floor could have played a role. Additionally, improper installation and connection of the slab might contribute to the observed damage, highlighting the multifaceted nature of potential factors influencing floor collapse in masonry structures.

Fig. 17. a. *Before earthquake (Google Street View, 2022) situation b. After the earthquake situation of the historic building of the Union of Chamber for Merchants and Craftsmen in Antakya, Hatay*

Potentially applicable interventions: When floor collapse occurs in a masonry structure, the potential damage extends beyond structural elements, impacting the stones themselves. In such cases, stone consolidation emerges as a viable intervention to address the damage sustained by the stones. The complexity of the situation necessitates a meticulous and detailed rebuilding application to restore both structural integrity and aesthetic cohesion. Introducing vertical-horizontal elements, commonly employed for retrofit purposes across various damage types, proves effective in mitigating the aftermath of floor collapse. However, the restoration process goes beyond mere replacement; there is an opportunity to recreate not only individual elements but the entire structure, incorporating original design principles. Section enlargement (Fig. 18a) in specific areas becomes a strategic consideration, offering a tailored approach to reinforce compromised sections. Additionally, the implementation of confinement techniques, utilizing both traditional and modern materials, presents a versatile solution to enhance the overall resilience of the masonry structure affected by total floor collapse. If the authenticity of the building is disregarded, jacketing such as in Fig. 18b may be employed as a potential intervention.

a. b.

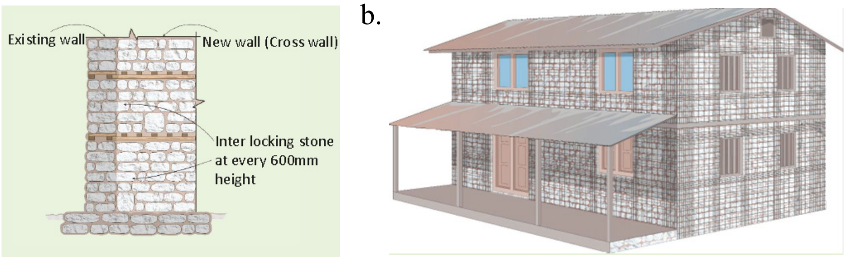


Fig. 18. a. *Detail of adding new wall* **b.** *Wire mesh jacketing application (Government of Nepal National Reconstruction Authority, 2021)*

DISCUSSION AND CONCLUSION

The repercussions of the Kahramanmaras and Hatay earthquakes on February 6 and February 20, and their subsequent aftershocks, have been analyzed to understand the effects on masonry structures and uncover the causes of damage. The study highlights that failures in masonry structures resulting from seismic loads can be ascribed to diverse factors, encompassing in-plane and out-of-plane damage mechanisms. Notably, issues like wall connection or detachment damage and total floor collapse may manifest due to inadequate detailing or insufficient load-bearing capacity. This comprehensive examination contributes valuable insights into the complex dynamics of seismic damage in masonry structures and sheds light on potential vulnerabilities.

By emphasizing established intervention techniques, the aim is to provide valuable insights that contribute to the ongoing discourse on enhancing seismic resilience in construction practices, acknowledging the significance of preserving structural integrity and historical value.

In the decision-making process for building repair or strengthening, a multitude of criteria must be carefully considered, encompassing technical assessments, cost evaluations, the historical significance of the structure, available technological solutions, the expertise of the workforce, project timeline constraints, and challenges related to building occupancy. These factors collectively guide the selection of the most suitable approach for retrofitting or rehabilitating a structure. In addition, it is imperative that the chosen method adheres to principles of reversibility, and compatibility with the original materials and techniques, and minimizes the overall impact on the structure.

While recognizing the importance of a comprehensive approach to repair and retrofit decision-making on masonry structures, this study primarily focuses on presenting fundamental methods for addressing damages caused by earthquakes. A summary correlating damage, potential repair, and retrofit methods within the study's scope has been meticulously compiled and is presented in Table 1.

Table 1. *Repair and retrofitting methods for masonry building damages (Black "*" signifies the utilization of the method in the described case buildings, while white asterisk indicates that the technique is applicable for similar damages.)*

Damage types in masonry	Interventions for Structural Masonry – Repair of Masonry: Repair of Cracks	Stone consolidation	-Both-: Local substitution /Replacement	Rebuilding / Reconstruction	Grouting	Adding vertical-horizontal elements	Repointing joints	Strengthening of Masonry: Jacketing / Reinforced coating	Section enlargement	Confinement	Buttressing	Base Isolation	Supplemental damping	Implementing a system or elements	Stitching
In-plane damage	*	* (white)	* (white)		*	*	* (white)			*		* (white)	*		*
Out-of-plane damage	* (white)	* (white)	*	*		*	* (white)	* (white)	* (white)	* (white)	*	* (white)	*	*	
Wall delamination	* (white)	* (white)	*	*		*	*	* (white)		*	*	* (white)			*
Connection damages	*	* (white)	*	*	*	*	* (white)		* (white)	* (white)		* (white)	* (white)	*	
Floor collapse		*		*		*	* (white)	*	*	*	* (white)	* (white)	* (white)	*	

Within the methods outlined in Table 1, those applicable to a wide range of damages include stone consolidation, adding vertical-horizontal elements, confinement, and base isolation. Following these general interventions, methods with high potential for application include the repair of cracks, rebuilding/reconstruction, and supplemental damping. While methods like stitching and grouting are highly useful, their application is typically reserved for specific cases.

The examples of potential interventions provided within the study for five different basic damage types are limited in their scope, considering the diverse range of potential applications. However, the aforementioned methods constitute fundamental measures for the repair and retrofit of masonry buildings, serving as pivotal initial steps. Throughout the implementation of these methods, compliance with contemporary earthquake engineering standards and regulations is imperative. Additionally, it is essential to incorporate an understanding of traditional masonry construction techniques that exhibit historical resilience, taking care of the reversibility and compatibility of the methods. Above all, reserving the historical value and authenticity of the building must be prioritized to the possible maximum extent, regardless of the chosen intervention.

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THE PARADOX OF CONSERVATION AND SUSTAINABILITY OF RURAL ARCHITECTURE

Zehra EMİNAĞAOĞLU[1]

1 Doç. Dr. Zehra EMİNAĞAOĞLU, Artvin Çoruh Üniversitesi, Sanat ve Tasarım Fakültesi, Mimarlık Bölümü.

ORCID: 0000-0003-4337-6860

1. INTRODUCTION

Rural settlements display unique architectural examples of the interaction between nature and humans. Rural architecture refers to structures built not by professional architects, but by master builders coming from the culture of daily life. It develops and changes with experiences over time. It is in harmony with its natural environment as a whole, both at the scale and at the settlement scale. Rural people, who know the vital value of soil and natural resources, have chosen harmony with nature in their architectural preferences. Climatic conditions, locational features, topographic conditions, traditions and customs, production and consumption activities, belief structure determine the emergence of rural architecture. For this reason, rural settlements, most importantly rural housing, reflect many traditional traces of the life and culture of the local people. Although housing has an important place in rural settlements, many structures such as haylofts, barns, warehouses and mills are also included in the content of rural architecture; the names of these structures vary from region to region.

Rural areas should be recognized as material cultural assets that should be preserved and transferred to future generations as concrete evidence of traditional life culture that has survived to the present day. However, in rural areas, which are shaped in harmony with their environment, many conservation problems arise as a result of new requirements arising from changing and developing technology (Aktaş, 2019). There may be various social, economic and architectural problems for rural areas. Among these problems, villages that are in the process of architectural aging or deterioration may face the danger of extinction due to economic hardship in settlements where agriculture and animal husbandry economy does not continue and the young population migrates (Eres, 2016). Stopping the processes of extinction or deterioration in rural areas is equivalent to keeping traditional culture alive. In this context, it is necessary to identify the conservation problems in rural areas and to give improvement suggestions for them (Aktürk, 2021).

Rural development is basically a political concept that aims to develop the rural population on the spot in order to achieve the ideal balance of socio-cultural and economic differences between urban and rural areas, thus solving migration and employment problems on the spot (T.C. Kalkınma B., 2018). Today, natural resources are damaged and destroyed due to reasons such as prioritizing the economic development dimension or ignoring the environmental dimension in activities carried out with the aim of sustainable development. As a result, development efforts in the economic dimension bring problems in the environmental dimension and the balance and harmony in the environment are disrupted (Bostan & Gül, 2017). Nowadays, from time to time, rural settlements are negatively affected by the results of economic development-oriented projects and go to extinction.

In this study, after the definitions and concepts related to rural architecture are given, the cultural heritage value and processes of rural architecture are discussed. In addition, the paradoxical relationship arising from the contradictions between the protection and sustainability of rural settlements is evaluated. Because the unlimited demands and needs, changing social and economic conditions against the protection of rural architecture, which is a cultural heritage value, lead to paradoxical contradictions between conservation and sustainability. In this study, it is aimed to discuss the events from a broader perspective both individually and organizationally with paradoxical thinking. The study is a case study, which is one of the qualitative research methods. The case study is used to describe, explain and evaluate conflicts arising from different social-cultural, economic and environmental phenomena. Case studies are the process of collecting, analyzing and analyzing data in a systematic way to determine the existing situation. In this context, the study evaluates the contradictions created by thinking together elements that are contradictory to each other but at the same time interrelated within a larger system.

1.1. Definitions and concepts

They are environments where folk architecture is common, reflecting the cultural structure and the lifestyle of the period they belong to. In contrast to the monotonous structuring of cities, which are increasingly similar to each other today, rural settlements are shaped by the physical environment and their unique lifestyles. Within the cultural richness of Anatolian society, they differ from region to region and even from village to village in the same region (Eminağaoğlu &Çevik, 2007). The word "vernacular", derived from the Latin word "vernacutus", means the dialect of a language or people in general use, while in architecture it refers to a qualifying condition (Oliver, 1997). From an architectural point of view, "vernacular" is used to convey an undifferentiated building form that is a member of a large and homogeneous group (Kuban, 1995). In the literature, vernacular architecture is referred to as traditional architecture, indigenous architecture, rural architecture, spontaneous architecture, folk architecture, architecture without architects, vernacular architecture, anonymous architecture, vernacular architecture. According to the definition of the World Encyclopedia of Vernacular Architecture, rural architecture includes all houses and other structures produced by the people (Çekül 2012; Oliver, 1997; Rudofsky, 1965; Hasol, 1995). According to Kuban (1995), vernacular architecture is the natural and organic construction of one's own dwelling with the help of local craftsmanship in common understanding (Kuban, 1995). Hasol

(1995) considers vernacular architecture under the name of anonymous architecture and defines it as architecture whose creators are unknown and which is the common property of the people (Hasol, 1995). It is built with the possibilities of the environment and local materials, mostly by the owner or local craftsmen using traditional techniques.

Rural settlements still appear today as environments that have preserved their local character in many regions; they contain examples of rational solutions in accordance with the richness of form, regional materials and local conditions that developed according to the conditions of the period. Original buildings that are similar in material, color, form, facade layout, roofs, and that differ according to the physical environment and social structure in which they are located, and their coming together add a recognizable feature to the settlement and determine the character of the rural settlement (Eminağaoğlu & Çevik, 2005). The architectural solutions developed by humanity in line with centuries of life experiences around the common mind form a harmonious pattern with each other. With this structure, vernacular architecture exhibits a character that develops over time and changes from building to building. Far from stagnation, local examples focus on rational solutions; they are built in extraordinary harmony with their natural environment and have almost no negative impact on the environment; in fact, they are the essence of today's ecological designs (Ovalı & Delibaş, 2017). In the book titled "Rural Architecture in Anatolia" prepared by Çekül Foundation, it is emphasized that rural architecture should be considered differently from traditional architecture, which has a refined understanding of design and style, including monuments, palaces and mansions. Rural architecture is an important source of inspiration for contemporary design, even though it is often dismissed as far from refinement. However, it is completely different from the understanding of "refined architecture", which is defined by stylistic features consciously added to the building by a professional architect with an aesthetic concern that goes beyond the functional requirements of the building (Çekül, 2012). Rural buildings are intended to meet certain needs and bear the traces of the culture of life, economic activities and spiritual values behind these needs.

When defining rural areas, the existence of many different social, economic, etc. factors has not made it possible to define a common definition that will be accepted by everyone (Ceylan & Sabuncu, 2018). In the definitions made on a regional basis, definitions have been made with many different criteria such as population, borders, economic activities, building characters. The links between lifestyles and settlements have made it necessary to distinguish between "rural" and "urban" in order to facilitate the expression of common characteristics. A general definition for rural settlements is all areas outside urban settlements. (Tütengil, 1977). Living areas that are far from cities, sparsely populated, dominated by agricultural activities, and preserving their naturalness are generally considered “rural”. The variables that stand out in this definition are; distance, solitude, agriculture and natural environment (Doğan & Yardımcı, 2019). Defining rural areas only as non-urban areas or areas where agriculture and landscape are prominent is insufficient to describe the complex situation of rural areas today (Labriniadis, 2006). The narrowing difference in meaning between urban space and rural areas points to the loss of the character and meaning of rural areas. Today, some of the rural areas, which are defined as “non-urban areas”, have been integrated with cities as a result of the expansion of cities. Urban pressure is increasing on rural settlements; this situation makes it difficult to preserve rural architecture and transfer it to future generations in terms of sustainability.

2. RURAL ARCHITECTURE AS CULTURAL HERITAGE

The new environments created by human beings with their knowledge and culture, using the natural environment they live in, are built-structured environments. Built environments reflect all the social values of the periods in which they exist. For this reason, it is an important source of common cultural heritage. Built environments, which include a wide scope from building scale to settlement scale, refer to the physical elements that make up the architectural structure. It is now recognized by all circles that architectural heritage is one of the most important components of cultural heritage. Every work done to reveal the aesthetic and cultural values of this heritage without disturbing the qualities that constitute its originality and identity is very valuable and important.

The existentialist approach, which emphasizes the uniqueness and importance of place, aims to reveal the reason for the existence of place. “Place” is an important concept in terms of representing the way of human existence in the world. In this context, it is important to ensure the continuity of the original qualities and meaning of places and to preserve their character. This leads to the idea of preserving the essence (nature) of the original values and qualities of cultural assets, that is, the reason for their existence. The meanings and values that are preserved and transferred from generation to generation define the concept of ‘cultural heritage’ (Koca, 2015). Traditional settlement patterns, which are indicative of a unique culture, are recognized as cultural heritage as long as they can transmit their unique character and reason for existence from generation to generation (Oliver, 1989). The settlement pattern, which is the result of the interaction between society and the physical environment, determines the character of the settlement. Settlement character includes the values and meanings of lifestyle, cultural activities, historical and aesthetic features defined by local people and accepted by generations. Values and meanings, knowledge, traditions and customs, which are formed by the common identity of the people, are transferred from one generation to the next, creating cultural heritage and forming the settlement pattern (Oliver, 1989). In the industrial world that was to be established, the rationalist principle, based on the cause-and-effect relationship between specific requirements and formal outcomes, was fundamentally opposed to the idea of constructing knowledge from what already existed. This tendency resulted in the eventual rupture of the historical continuity of the built environment and led to the loss of a common architectural language due to the increasing obsession of each architect with self-expression (Fathy, 2010). However, while in urban areas the rapid flow of trends, renaissance, baroque, neoclassical, eclectic, rationalist, post-modern and minimalist buildings have been produced, set aside and lost their popularity over time, traditional communities have continued to meet their needs as their ancestors did for centuries (Baca & Lopez, 2017). In the rural context, vernacular architecture has followed the natural environment as well as the relationships of its own social structures. In this context, rural architecture appears as a presentation of different lifestyles and habits, values and meanings that have accumulated in a society. In this respect, rural architecture ensures the continuity of history as a cultural heritage.

Cullen (1961) draws attention to how the new design practices of Modernism have destroyed the original character and sense of place of settlements. Drawing attention to the interaction within the community, he defines settlements as 'the art of relationships' and emphasizes the distinctive features and values of places and states that all the elements that make up the environment should be evaluated together (Cullen, 1961). In the rural context, vernacular architecture has followed its own pace and forms of social bonding as well as the natural environment. Vernacular architecture should not be seen as something frozen in time, something belonging to the past, but on the contrary, it is living, evolving with time, socially and culturally connected and current (González, 2006). In other words, vernacular architecture is a rich storehouse of knowledge that is still alive, especially in relation to the social needs that a settlement area can meet, in order to make the best use of the natural environment and its resources, to achieve results and to solve problems. It is the product of accumulated social practices, whose forms and typological characteristics have been preserved and at the same time carried forward with new experiences. When it comes to vernacular architecture, the Venice Charter not only emphasized the importance of more "modest" creations, but also organizations such as ICOMOS established the International Committee for Vernacular Architecture in 1976 to promote the study and preservation of vernacular architecture. The 14th General Assembly of ICOMOS in 2003 adopted the convention Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage. One of the articles of this convention under the title of General Criteria is "The value and authenticity of architectural heritage cannot be based on narrowly defined criteria because respect for all cultures requires that they be evaluated within the cultural framework to which they belong" (ICOMOS, 2003). The concept of "authenticity", which is a criterion for organizations such as UNESCO and ICOMOS in determining cultural heritage values, has been restructured since the 90s. According to the 1994 Nara Document on Authenticity (ICOMOS 1994), the elements that constitute the authenticity judgment are related to both form and design in order to preserve cultural heritage in all its forms and historical processes. The unique value of cultural heritage is defined by the holistic evaluation of its tangible and intangible values in terms of design and form, materials and objects, use and function, traditions and techniques, spirit and expression. Rural settlements and rural architecture are cultural heritage areas that achieve perfect harmony in the interaction of human beings with nature, are shaped specific to the place and contain unique characteristic values, and gain historical value by transmitting the socio-cultural values of the society. Rural architecture includes unique structures shaped by climate, topography, life culture, production-consumption activities and built with experiences. The greatest chance is that in a world changing with globalization and where everything is rapidly consumed, original examples of rural architecture can still survive. Turkey has geographies with unique examples of rural architecture in seven different regions, even in its own local region.

3. RURAL ARCHITECTURE AND CONSERVATION ACTIONS-POLICIES IN TURKEY

Rural architecture is shaped by the geographical structure, life culture and physical environmental conditions. Generally, construction and settlement principles based on experience have brought the right results and qualified cultural landscape and architectural products have been obtained. Traditional rural architecture in Anatolia is as rich and diverse as urban architecture. Rural architecture, which describes a culture of life, is no longer produced or used in any place due to various reasons such as usability, economic obsolescence or obsolescence. Even if "conservation" is in question for living and inhabited environments, the context is different. When considered in the context of sustainability, "conservation" is important for cultural productions that represent a past period, its users, needs, architectural trend, understanding, culture of life, etc., which may have completed their function but are important for cultural productions.

Since the early years of the Republic, efforts have been made both to ensure economic development in the village and to realize the health, cleanliness, beauty and modern cultural life targeted throughout the country in the village. Tekeli stated that while the space of modernity in the West was the city, in the modernity project of the Republic, overcoming the differences between the city and the village and the spatial arrangements of the village had an important place (Tekeli, 2001). In 1924, the Village Law No. 442, one of the first laws of the period, was enacted. In the years following the enactment of the Village Law, the First Economic Congress and the First Village Congress were held, the Settlement Law was enacted with the aim of making landless peasants landowners, and the establishment of Village Institutes to provide education in rural areas was seen as successful policies for rural areas in the period until the 1950s (Kayıkçı, 2005). While a country that had just emerged from the war was getting back on its feet, there was restructuring in every corner of the country, whether urban or rural. Turkey, whose development process continued with industrial policies until the 1960s, continued its development process with development plans with the planned period in the 1960s. In 1963, starting with the first five-year development plan, policies for rural areas were developed in five-year development periods and solutions were sought for the problems of the period in rural areas; studies were carried out for development in rural areas with different approaches. With the National Rural Development Strategy (NRDS) documents prepared regularly since 2007-2013, changes and developments in approaches to rural areas have been identified. Policies towards rural areas in Turkey have been influenced by the development policies in agriculture and rural areas with the aim of modernization in the republican period. In this period, rural areas, which accommodate 75% of the population and are seen as important production centers in the country's economy based on agriculture, have maintained their importance and the importance attached to agriculture and rural areas has continued. The importance of the agricultural sector on both the economy and social life in rural areas continued until the 1970s (Gülçubuk et al. 2016).

In Turkey, rural planning is not a type of planning with its own legislation. In development plans and strategy documents, rural areas are mostly addressed within the scope of rural development policies and the spatial dimension is missing. Although regional plans identify spatial strategies for rural areas, they generally produce sectoral decisions (Öztaş & Karaaslan, 2017). Here, "spatial planning" is not considered as traditional land use planning, but as the realization of the future vision of a place or region through a series of policies, priorities, programs and land use, and ensuring coordination between all these (Gallent et al., 2008). In the environmental layout plans and master development plans, rural areas are left as "areas to be preserved as they are" (Öztaş & Karaaslan, 2017). In this process, while life continues in rural areas that are cultivated, planted and produced, the problem of protecting rural areas and structures used by their owners is not on the agenda. The rural buildings produced by the culture living in rural areas are suitable for the understanding and needs of the period. Problems related to rural architecture and its protection have emerged in the process in connection with multidimensional problems related to rural areas.

Although Turkey has generally adopted international conventions and approaches related to conservation, the legal regulations do not include the definitions of rural areas or rural protected areas, and are described as "cities and places subject to social life" (Eres 2013). With the 1964 Venice Charter, the boundaries of conservation were expanded to include all kinds of urban and rural textures bearing the traces of the past and assets that have gained cultural meaning through historical development (Günay, 2006). As far as vernacular architecture is concern not only has de Venice Charter highlighted the importance of the more "modest" creations, but also organizations such as ICOMOS established the international committee of vernacular architecture in 1979, to support the study and conservation of vernacular architecture, implementing new methods and preservation strategies and trying to promote an international multidisciplinary network, among other goals (Machat, 2002). Immediately after the 1964 Venice Congress, the Supreme Council of Real Estate Antiquities and Monuments (GEEAYK) in our country accepted the Venice Charter with a decision and the text of the statute was published for the first time in the Foundations Magazine in 1968. However, although these developments are seen as an indication of a conservation approach, in practice during this period, the main focus was on the protection of archaeological artifacts and preventing them from being taken abroad (Akozan, 1977). Turkey ratified the Convention for the Protection of the Architectural Heritage of Europe on October 3, 1985. Thus, the Convention, which recognizes the built environment of the Council of Europe as the common architectural heritage of the whole of Europe and commits to its documentation, protection and maintenance, entered Turkey at the legal level. In 2003, Turkey signed the European Landscape Convention, confirming the value of rural landscapes and the need for their protection (Eres, 2013).

After the 1970s, protected areas, which had been seen as almost the only tool to protect rural areas, were questioned; debates began about whether protected areas were sufficient to prevent environmental destruction. Despite strict planning controls, complete protection cannot be ensured (Öğdül, 2019). In 2012, the inclusion of villages within metropolitan municipality boundaries with the Law No. 6360 is a turning point for rural areas as well as for rural planning. With this law, planning of rural settlements has become one of the main issues. According to the law, district municipalities or, if requested, metropolitan municipalities shall make or have made type architectural projects in accordance with the traditional, cultural and architectural characteristics of the region in line with the current zoning legislation for non-commercial buildings in villages transformed into neighborhoods (law). This decision has caused concern among scientists and academia due to the negative consequences of political pressures on the protection and sustainability of rural areas. Concerns have been expressed that traditional life and identity will be lost, construction will increase rapidly and multifaceted negative consequences will emerge due to the exposure of villages connected to big cities to zoning practices (Öğdül, 2013). In 2020, with the amendment made to Article 8 of the Zoning Law No. 3194, it was decided that the metropolitan municipality council would decide whether the rural settlement characteristic of the places with a population below 5,000, which were transformed into neighborhoods due to the metropolitan municipality boundary becoming the provincial boundary, continued to be rural settlements. The changes in the administrative character of rural settlements that will occur with this amendment have brought the concerns about Law No. 6360 back to the agenda. According to Öğdül, when the legislative amendments are monitored, there is a systematic effort to encourage construction in rural areas. For example, although there are very strict rules regarding the misuse of village middle properties (pastures, pasture, winter pasture, grazing, threshing and fairgrounds), which have been used since ancient times and are not subject to private ownership, ways are being sought to open pastures for construction. Pastures are vital for small and medium-sized agricultural enterprises and are also essential for healthy food production. While the misuse of pastures is punishable by imprisonment for up to three years according to Article 154 of the Turkish Penal Code, with the amendment to the Metropolitan Law, there is concern that pastures, plateaus and winter pastures within the municipal boundaries will not have the same status and that the legal dimension of misuse will be controversial (Öğdül, 2013). There are different opinions on Law No. 6360. It is emphasized that the inclusion of villages within metropolitan municipality boundaries with the Law is a turning point for rural areas as well as for rural planning. It is stated that it has given local governments the opportunity to develop innovative and participatory approaches to rural areas; that while rural areas were previously shaped by central policies, each local government now creates its own approach; and that some local governments develop rural policies and strategies for the entire province, provide farmer support, and organize local production (Öğdül, 2019).

Planning instruments for the protection of the countryside have not been developed except for restrictive planning decisions, which have mostly failed. In the first years of the 2000s, with the

influence of EU spatial integration policies, rural areas and rural-urban definitions started to be discussed in planning, but they did not find a practical fulfillment. It is difficult to say that rural spatial planning was a prominent agenda for our profession until the early 2000s. In Turkey, documentation of rural architectural heritage began to be carried out systematically in 2000. The Turkish Academy of Sciences (TÜBA), with the support of the Ministry of Culture, established a system called the Turkish Cultural Inventory and developed a "rural architectural settlement and building fiche" to identify urban and rural architectural heritage and conducted studies in pilot regions. In addition, ÇEKÜL Foundation, which conducts comprehensive studies on the protection of rural architectural heritage in Turkey, identified 38 rural settlements from different geographies within the framework of the Rural Heritage Program and conducted an examination under the headings of rural change, conservation problems and what needs to be done to maintain their vitality (ÇEKÜL, 2020).

Although not mentioned in the Regulation on the Construction of Spatial Plans, "village design guides", which aim to protect the original characteristics of villages, were added as an additional article to Article 8 of the Zoning Law No. 3194 in 2013. According to the relevant additional article; village design guides can be prepared by the relevant administrations with the participation of the mukhtars in order to protect, develop and maintain these features in villages that are important in terms of settlement and construction characteristics, architectural texture and character, development level and potential. village design guides are approved and implemented with the decision of the relevant administrative council (Law). The development of a tool for villages with "village design guides", which aims to protect the original qualities of villages, is an important step in terms of conservation. The establishment of a unit for rural areas in the Ministry of Public Works and Settlement, which was the central institution for spatial planning during the period, is an important indicator. The Ministry collaborated with universities and TÜBİTAK to create a model on the place of rural planning in the planning system and the preservation of vernacular architecture in rural settlements (TÜBİTAK, 2014; Öğdül, 2019). The preparation of guidelines for the preservation of vernacular architecture was initiated with two projects for Kayseri and Balıkesir provinces (Öğdül, 2019).

With these institutional approaches, it seems possible to effectively use tools such as village design guides with place-specific content that emphasize rural identity. In this direction, it is aimed to obtain locally appropriate housing projects to be given to villagers on the basis of geographical regions or provinces. Following this study, the ministry has developed "housing projects suitable for local architectural features" in many provinces. With these type projects, it is thought that new buildings will be suitable for the rural character and natural environment. In this period, spatial studies on rural settlements were mainly directed by the central government and limited to housing production.

Considering this general situation, in the conservation strategies to be established in order to ensure the sustainability of many rural archaeological landscapes protected against development pressure; tools are needed to define and address the natural and cultural environment as a whole, to ensure the continuity and participation of local groups living in that area and connected to the area together with their social values, and to support them with economically sustainable tools and methods in all conservation efforts (Naycı, 2014). There are various social, economic and architectural problems in rural areas. According to Eres (2016), in settlements where the agricultural and animal husbandry economy does not continue and the young population migrates, villages that are in the process of architectural aging or deterioration face the danger of extinction due to economic hardship (Eres, 2016). Many conservation problems arise as a result of changing and growing technology and changing needs of rural areas, which are shaped in harmony with the topography they are located in. Traditional houses built in rural areas reflect many traditional traces of the life and culture of the local people. Rural areas should be recognized as material cultural assets in order to preserve and transmit the traditional life culture of the past to future generations. Stopping the processes of destruction or deterioration in rural areas is equivalent to keeping traditional culture alive.

4. THREATS TO RURAL ARCHITECTURE

The necessity to protect rural architecture emerges with the existence of elements that threaten rural architecture. The elements that wear out, age and destroy rural architecture can occur in a long period of time or in a very short time. Depending on the topographical location, "aging" occurs in buildings exposed to climatic conditions in a long process, causing organic elements to form and these elements to damage the structure. On the other hand, factors such as earthquakes and fires can destroy buildings and even entire settlements in a very short time. Another reason for the disappearance of rural architecture is local, regional or national policies. These policies may lead to wrong land uses such as opening agricultural lands and pastures for construction. In addition, the lack of policies regarding these regions also causes harm in terms of conservation. Investments such as dam construction and mining activities completely destroy rural settlements. When the economic conditions that guide the development of rural areas fail to keep pace with the requirements of the age, they can pose a threat to rural settlements in a wide range of areas. Changes in the way of production, traditional production techniques, and new commercial areas can change the rural character, as well as causing neglect, structure and infrastructure deterioration when the change cannot be kept up with. Threats to rural architecture occur under various factors. Within the scope of the study, the factors threatening rural architecture are classified as social and cultural, economic, policies, new constructions, environmental and climatic conditions. It is not possible to consider the elements in this classification independent of each other. They all take place in interrelated, intertwined and triggering events.

Social and Cultural Aspects: In rural settlements, inadequate or non-existent education, health and cultural services, as well as difficulty in accessing these services, unemployment, agricultural inefficiency, inadequacy of public investments and services, inadequacy of infrastructure and transportation facilities lead to the abandonment of rural areas. There is dissatisfaction with living conditions caused by lack of education, social and economic conditions. The widespread use of mass communication tools together with the developing technology has led to the envy of urban life, especially among young people. Migration from rural settlements to cities with the expectation of better living conditions and aspiration for life in big cities. Abandoned rural houses are being demolished and destroyed over time. The disappearance of rural architecture shaped by rural life culture causes the loss of our ties with the past. Developments all over the world are also changing the culture of rural life. The wishes, needs and expectations of people living in rural areas are changing. Technological household appliances such as television, telephone, refrigerator, washing machine, and oven have taken their place in rural houses. In the past, every family used to bake bread at home, but now there is a bakery in the villages or bread is bought from the nearest center. People now want to live in villages as they do in the city. New needs create new spaces or change the existing rural houses. Changes made in rural houses or new spaces emerging with the changing social structure negatively affect the rural architectural identity.

Economic Elements: The most important economic-based factor is the deterioration of the economic structure that governs and directs rural areas. In rural settlements, which are shaped by a certain mode of production and economic relations, when they cannot keep up with the change and development of conditions, especially the young population migrates. It is faced with structural deterioration with villages where the elderly population remains and even empty villages. In some cases, economic changes are subjected to excessive pressure from functions such as tourism and industry in rural areas.

This overloading leads to deterioration of the scale and quality of rural architecture and negative changes in building identity. Multi-storey reinforced concrete buildings that are not in harmony with the local structure and the natural environment, traffic routes that are carelessly opened through nature, increasing traffic, and the pollution caused by this also create negative effects. Changes in the way of production, the arrival of factories, large commercial and business centers in rural areas instead of traditional production techniques and products, while necessary and important for the development of the region, may negatively affect the natural and architectural structure of rural environments. Planning and project design in this direction, taking into account the local identity and natural environment, is of great importance for the protection of rural environments.

Policies: Management and planning decisions regarding the natural and cultural environment are one of the most important tools to control change and development. They form the frameworks for determining new construction areas, ensuring the quality of construction, and ensuring that existing values and local identity are not deteriorated. Failure in planning and management leads to the introduction of inappropriate functions in terms of both quality and scale, deterioration of the rural landscape character, erosion and even destruction of rural architecture. Regulations for rural areas show periodic changes depending on the dynamics of legal regulations. Even though the regulations in question are hopeful for the development of rural areas whose status has been changed or given new status, they pose threats that enable wrong land uses. The interests of rural settlements should be taken into consideration when implementing laws on issues such as the transformation of areas under disaster risk, the need for new settlement areas, the status of areas such as pastures, etc.

Public/private sector investments such as dams and hydroelectric power plants on rivers, wind and solar energy investments, investments in mineral resources, investments in land, sea and air roads are examples of political factors that threaten traditional rural environments. Investment decisions taken within the framework of national development often damage and destroy rural areas and rural settlements. For example, with the construction of the Keban dam, 59 villages, 26 hamlets and 6 communes were completely submerged, 104 villages, 24 hamlets, 2 communes and 11 neighborhoods were partially submerged, totaling 39,300 hectares (Çotur, 1990). The Derbent dam built on the Kızılırmak can be shown as another example. In 1991, 200 houses, 17 km^2 of agricultural land and the ancient city of İkiztepe, which dates back to 4000 BC, were flooded due to this dam, which became operational within the borders of Bafra district of Samsun province (Sever, 2005). Similarly, with the Deriner Dam constructed in the

Çoruh River Basin, expropriation was made on 8,810 parcels of land in 30 villages in the region and three villages were completely submerged. Due to the Yusufeli Dam, which was last constructed in the same basin and completed in 2023, 1 district center (Yusufeli) and 7 villages were completely submerged, 22 villages were largely affected and 32 villages were partially affected (Sönmez, 2012). With the data of only four examples given here, it can be seen how rural areas and settlements are destroyed by dam construction.

World wars, wars between countries, civil wars, conflicts, terrorist incidents, security problems, forced migrations, political discrimination and oppression policies, racism, etc. factors that cause rural settlements to lose their population are also seen as political threats (Güler, 2019). Political decisions such as forcing people to migrate from the regions where they live or the forced evacuation of those living in settlements in regions where conflicts take place due to security threats cause rural settlements to become empty and the structures in these settlements become old, destroyed and unusable over time. Returns to villages have gained momentum within the scope of the "Return to Village and Rehabilitation Project" in order to ensure back migration and re-establish rural life in abandoned rural settlements. In order to restart life in the returned villages and to make it permanent, the necessary works for the creation of the necessary village infrastructure and the necessary works for the improvement of activities such as agriculture, animal husbandry and handicrafts have been initiated by the state (T.C. İçişleri B., 2010). In the physical arrangements for the returned village settlements, it will be important to ensure the interaction of old and new in the name of sustainable approach.

New Structures: New constructions in rural areas are among all the elements that threaten rural architecture. The images created by new dwellings built as a result of migration back to the countryside or the desire to acquire second homes in these regions do not harmonize with rural environments. Accommodation structures built within the framework of creating tourism opportunities economically create dominant images in rural areas in terms of scale. In new transportation routes opened for rural settlements with intense tourism pressure, the natural environment is destroyed with unnecessary road widths. The spread of urban lifestyles in rural areas negatively affects the quality of the rural built environment, especially the quality of the housing texture. The rich and unique rural building culture with its rural architectural texture is under the threat of excessive consumption and mass production forms brought by modern life. City dwellers who return to their villages or buy second homes are looking for the same spatial quality in the village as they experienced in the city. Even the local people living in the village want to shape their houses with the possibilities of modern life.

Traditional village houses were built with natural building materials such as stone, wood and adobe. For this, quarries, forests and clay soils in the immediate vicinity of the village were used. Today, it is not easy to find these materials and the craftsmen who know traditional construction work are no longer trained. Reinforced concrete structures are preferred (due to easy labor, easy material supply, and being more economical) due to the difficulty in obtaining materials, the inability to find suitable craftsmen for construction works that require craftsmanship, and even if all these can be provided, they are economically costly. One of the most important and grave practices that threaten rural architecture is the demolition of old traditional houses in order to use wood and stone materials in new reinforced concrete structures. At this point, it is necessary to raise public awareness and support the values and qualities of rural architecture and its importance for social and cultural sustainability.

Natural Conditions: Rural architecture is developed by taking into account the environmental conditions of the region (such as topography, landscape, climatic conditions) and experiencing them. Environmental and climatic conditions are taken into account in matters such as the location and orientation of the house on the land, the size and position of the door and window openings on the facade, and the choice of materials. For example, in the Black Sea Region, where the climate is characterized by heavy rains, chestnut wood, a durable type of wood, is preferred in traditional-rural buildings, while the roof eaves of the building are made up to 1-1.5 meters wide to partially protect the building from rain. For this reason, traditional-rural buildings are long-lasting structures that reach centuries. However, it is not possible to withstand natural disasters such as earthquakes, fires and floods. Earthquakes, fires, floods, erosion, landslides, volcanic eruptions, avalanches, etc. are unpredictable and sudden natural disasters that cause rural settlements to lose their population (Güler, 2019). As a result of disasters that cause loss of life and property, rural settlements are sometimes completely destroyed and sometimes partially damaged and become unusable. In cases where there is a risk of disaster such as landslides, volcanic eruptions, earthquakes, they are evacuated. The inevitable end for rural settlements with disaster and disaster risk is the evacuation of settlements and migration of people. The most important issue in natural disaster conditions is to take all kinds of measures to ensure life safety.

5. THE PARADOX OF SUSTAINABILITY OF RURAL ARCHITECTURE

Existence is quite paradoxical since the journey of "acquiring a place", which begins with the existence of human beings, is constantly moving with a process of displacement. For this reason, the concept of paradox, which finds expression in concepts such as "logical conflict, contradiction, impasse and dilemma", appears as an effective tool and method for many disciplines in the discovery of reality. The problematic of "reality", which has been questioned around the concepts of existence-non-existence, real-false, sacred-worldly and multiplicity-singularity since ancient times, finds itself through paradoxical phenomena and situations for other disciplines that concern the individual and society, especially architecture (Akpınar, et all, 2021). Paradox means "counter-acceptance" or "logical contradiction" formed by the combination of the Greek words "para" meaning opposite, opposite, other, opposite and "doxa" meaning acceptance, delusion, idea, belief, thought. The difference from pure contradiction is that it is used for undecidable and unsolvable situations that can be determined as "neither right nor wrong" (Durhan, 2019). It can be defined as the combination of two phenomena that are not expected to occur together or two qualities that are not expected to exist together, two opposing thoughts (Atalay & Tüzün, 2017). Paradox is the simultaneity of incompatible, opposite, contradictory elements. For this reason, it is a concept used to describe situations that are difficult to decide and inextricable. In this section, the paradoxical relationships between the dilemmas of urbanization and rural conservation, development and sustainability, technological advances and conservation will be discussed. On the one hand, environmental thinking (including environmentalism) is emerging in a "hybridized" (technologies, modified natures, pollutants, wastes, etc.) or "ecological" society, where all (economic, social and political) actions, natural and social assets are increasingly inexorably interconnected; on the other hand, environmentalism is about the need for a clear distinction between the two spheres again, in order to more clearly separate nature from its social impacts. This paradox has recently attracted the attention of human geographers, especially those working in nature conservation and landscape protection (Murdoch & Lowe, 2003). Urbanization is seen as a feature of modern development. Urban development is increasingly affecting rural nature through its sprawl beyond its borders. Although its boundaries are demarcated by legal statutes, economic, social and political processes transcend these boundaries. It is the beginning of paradoxical relations, as it tries to maintain the modern-rural or urban-rural distinction on the one hand, while on the other it is involved in a complex network of hybrid relations.

Industrial change has occurred primarily in urban areas, and the rapid and uncontrolled development of industrial growth has both negatively affected urban living conditions and led to a re-evaluation of the countryside as a place of "escape". Thomas argues that "the growth of cities has led to a new rural way of life". The migration of the population back from the city to the countryside, contrary to the divergence in the planning system, is paradoxically partly encouraged, rather than hindered, and partly seen as a success of conservationist policy. On the one hand, while it is argued that rural nature and rural architecture should be protected, tourism is encouraged for this purpose, paving the way for new constructions. The relationship between the economic development of rural areas and sustainability appears as a paradoxical relationship. Even if the renovation and transformation efforts made for rural architecture for this purpose are evaluated as a positive development in terms of sustainability, new constructions create a paradox in the name of sustainability in rural environments. Whether the new situation will create a more livable environment or not seems to be a problematic situation. This paradoxical situation is the discussion on rethinking and practicing the meaning, value and forms of experience of rural space, creating new possibilities intellectually and exploring other living possibilities in rural environments.

The development of agricultural practices and techniques, and the access and utilization of developing technological opportunities to rural settlements are necessary in order to keep up with the times and to provide employment in rural settlements. Today, in most rural areas, people have both large vehicles such as tractors and automobiles. Wide, linear roads and parking areas are required for these vehicles to travel and park in the village. However, this is not possible in villages with narrow, curvilinear or even dead-end streets, so the transportation texture of settlements is changed over time. The contradiction of providing modern equipment while preserving the original identity and landscape character of rural settlements is a problematic situation. All these contradictions need to be evaluated and solved by expert groups. Sustainability of rural architecture is a multidimensional and interdisciplinary issue.

As a result of political decisions such as national and regional development policies and investments such as dams, hydroelectric power plants and mines made for development purposes, rural settlements are partially or completely destroyed. This paradoxical relationship between development and sustainability is an authoritarian approach on top of the protectionist approach. In the context of sustainability, a paradox can be defined as a combination of situations, decisions or areas with defined and specific tasks that, when combined, turn against themselves. Political decisions and investments implemented for development create situations that are opposed to the protection of rural architecture, which is valued for its historical, cultural, natural and unique qualities, and sometimes even protected by legal status.

In our country, the scientific conservation process is only valid for buildings that are registered and defined as "cultural property". Therefore, demolishing or arbitrarily repairing an unregistered simple village house does not pose a legal problem for the property owner. This situation can be interpreted simply as "then we can register and protect historic village houses as soon as possible", but this would be an approach with little practical reality (Eres, 2016). For village people who do not have economic power today, the registration of their houses means that even small, economic repair interventions that will keep their houses standing cannot be made. Going even further, traditional houses can be rapidly destroyed for the possibility of registration. The fact that practices carried out with the approach of protecting rural architecture accelerate the destruction of traditional-rural structures creates paradoxical results in the name of sustainability. With modernization, many traditional settlements were either abandoned or left to disappear, or they experienced changes as a result of urban transformation, expansion pressure and wrong policies. The historical role they acquired over time has been lost and the collective consciousness that constitutes their original character has eroded. This has led to contradictions between land use and its raison d'être. Therefore, defining the distinctive character of traditional settlement patterns, in terms of conservation practices, is in a sense discovering the local and revealing the raison d'être of these settlements (Koca, 2015).The cognitive and normative values of individuals in a particular settlement, combined with a shared history, create a cultural heritage that lasts for generations. This cultural heritage -even if it carries different meanings in different periods- is sustainable and has continuity because it has meaning for everyone in the society (Oliver, 2006). In this respect, in a world in constant change, it is seen that the preservation of cultural heritage can only be possible by preserving the essence of meaning and the values that make up that meaning. Otherwise, the preservation and sustainability of rural architecture will remain in wishes.

6. INSTEAD OF CONCLUSION

It is seen that the rural architectural heritage is deteriorating and disappearing as a result of constructions contrary to the environmental and physical characteristics of the region, without taking into account the rural settlement texture, rural-local architectural features and the needs of the local people. The spread of urban-oriented lifestyles to the countryside negatively affects the quality of the rural built environment. Rural architecture and rural settlement texture are under the threat of Excessive consumption and production patterns brought about by modern life and investment policies for development purposes. Just like in cities, rural areas should be considered together with employment areas. The survival of rural settlements will be possible with agricultural production areas, fields and gardens. It is necessary to provide resources to sustain the lives of people in their villages. Interventions independent of the wishes and needs of rural residents are not socially sustainable.

The problem of local and regional development policies cannot be solved from a unidirectional perspective and only with economic approaches. For this reason, it is necessary to harmonize with local people and the environment and to address development in a broad and multifaceted manner. In this context, "sustainable development" gains importance as a concept that establishes the relationship between past, present and future. Sustainable development needs to be perceived correctly and analyzed well due to its multidimensional (cultural, economic, social, environmental) and dynamic content. Between the contradiction of existence and extinction, sustainability turns into a paradoxical idea. Instead of focusing on eliminating the problem, it is necessary to address the problem from all angles and examine opposing ideas from all perspectives, aiming to provide different opportunities.

When developing policies and plans for rural areas, rural settlements should be viewed from a broad perspective. Their impacts at the planning level should be considered multidimensionality, and the opinions, wishes and expectations of the local people should be taken into account in a participatory approach. In addition, local specificities in the details of daily life and space should be recognized, their values should be preserved and transmitted. Different planning and design decisions regarding rural space should produce diversity rather than paradoxical contradictions.

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