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The Origins of Reinforced Concrete Interventions to Historic Structures in Turkey

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ABSTRACT
Reinforced concrete interventions have been a critical issue for restorations in the field of conservation since the early twentieth century. Until the twenty-first century, cement-containing interventions could be seen in almost all restorations in Turkey. There are even examples of monumental buildings whose structural systems have been converted to reinforced concrete. However, in more recent years in Turkey, reconstructions with echoes of stylistic unity began to emerge, with less of a focus on preservation and without consideration of the documentary value of the reinforced concrete used in the strengthening interventions of the twentieth century. From a structural viewpoint, it is necessary to assess whether mixed structures of reinforced concrete and masonry work well. From a conservation viewpoint, despite negative perceptions of reinforced concrete, these historic interventions have avoided confusion or falsification where the precise original nature of the structure is unknown. With these remarks in mind, this study describes the origins of reinforced concrete interventions in conservation in Turkey. It provides a general framework of the concept of interventions for strengthening and preservation at the intersection of reinforced concrete, earthquakes, codes, and conservation theories by tracking experiences with reinforced concrete from the Ottoman Empire to the early years of the Republic of Turkey.

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construction history; earthquakes; reinforced concrete; restoration, consolidation; Turkey

1. Introduction

The development of reinforced concrete (RC) coincided with the rise of conservation consciousness at the beginning of the twentieth century. In that period, the fields of both construction and conservation underwent numerous advancements and merged in the context of monument restorations. The construction industry saw an increasing preference for RC due to its technical, economic, and durability advantages over masonry structures. Particularly in post-catastrophe settings, for structural safety, RC was preferred both for new buildings and in consolidating monuments and existing masonry buildings with increased structural confidence. In subsequent Periods marked by the impact of world wars, RC was inevitably employed to restore and strengthen damaged or partially destroyed monuments. From France and Italy, where it was first and most widely used in restoration, to other countries that implemented interventions on a comparatively reduced scale, RC gained a firm place in the field of conservation around the world (Calderini 2000; Calderini 2008; Carbonara 1981; Esponda 2004, 2010; Theodossopoulos and Gratsia 2020). In the Ottoman Empire, RC was embraced by the construction industry early on as a new technology imported from Europe. However, the late institutionalisation of conservation and other complex factors specific to Ottoman and Turkish history altered the path of advancement in the intentional use of RC in strengthening monuments.

RC, introduced as a symbol of engineering progress, is new and modern. Conversely, conservation focuses on traditional structures and authenticity. These two semantically opposing concepts converge in interventions where modern materials and techniques are incorporated in historic masonry structures. At the beginning of the twentieth century, this contrast was viewed positively in the field of conservation. The ease of interventions for monuments and the notable difference of such interventions from the original parts are key characteristics of RC, effectively precluding the criticisms of 'falsification' that began arising as conservation shifted from stylistic restoration to scientific conservation. However, as charted in Supplementary Figure S1, there are drawbacks to RC as well as advantages. In the earliest years of RC applications, concerns primarily entailed questions of aesthetics and architecture as cement and concrete are non-original materials and not compatible with authentic historical parts. From

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a technical point of view, while the lack of confidence in masonry structures created a favourable environment for the adoption of RC, the weight and rigidity of the concrete raised concerns regarding its structural effectiveness. Despite doubts about the compatibility of these two construction techniques, the use of RC in conservation was promoted at the beginning of the twentieth century (Calderini 2008, 31). It was accepted in the Athens Charter for the Restoration of Historic Monuments in 1931 and it remained popular through the end of the twentieth century with the further support of the Venice Charter of 1964, which states that in cases where traditional techniques are insufficient, the conservation of a monument can be achieved using modern techniques.

Initial doubts and questions regarding the application of RC were soon answered by experience and direct observations of RC-related damages. Time showed that physical and chemical deterioration can occur on the material level when cement is combined with masonry. Moreover, since the 1990s, various earthquakes have shown that these distinct structural components exhibit different structural and seismic behaviours, resulting in severe structural damage (Lagomarsino and Podestà 2004a, 2004b; Sbrogiò, Saretta, and Valluzzi 2023; Sisti et al. 2022). From a conservation perspective, the term "reversibility", not mentioned even once in the Venice Charter, was involved in ICOMOS charter "Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage" prepared in 2003 (ICOMOS Charter 2003). In this point of view, RC interventions have been largely irreversible. Even today it is not easy to replace them with more suitable materials after new knowledge is acquired or new technological advancements are made. Reinforced concrete interventions become inappropriate according to this principle after this charter.

In Turkey, the use of RC in conservation was first formally addressed in legal conservation texts in 1936 (Vakıflar Umum Müdürlüğü 1936). The idea of concealing RC led to numerous interventions on various scales, encompassing both consolidation and reintegration. The use of concrete was historically intensive in Turkey, and in many cases, the materials or applications were of low quality. Many interventions with cement and RC effectively approached monuments as if they were being rebuilt from the plaster to the structural system. At the end of the twentieth century in Turkey, criticisms of RC increased, but they generally focused on the escalating negative chemical effects of cement rather than being grounded in structural experience or assessment (İnan Ocak 2021). In the following years, critics of RC shifted their attention to inauthenticity in conservation. Accordingly, many RC additions were dismantled, even if there were no structural problems.

Despite these negative perceptions of RC, such interventions can be viewed as layers showing the evolution of monuments over time. RC interventions exemplify a vital part of conservation history in Turkey, as well as in Europe. By contemporary international conservation principles, it is crucial to justify the decisions that are made (ICOMOS Charter 2003). Dismantling and reassembling should be avoided, as emphasised in the Athens Charter. Furthermore, architectural heritage possesses merits in not only its historic appearance but also the integrity of its components, including the concept, techniques, and significance of the structure in both its initial and subsequent states, the latter of which may include RC interventions.

Taking these considerations as a starting point, this study explores the origins of RC interventions in conservation in Turkey. As the use of RC has surpassed the century mark, it is crucial that architects, engineers, and public decision-makers understand the history of these interventions while determining their future. With the help of previous research exploring the cultural and technical factors that led to the spread of RC in European conservation efforts (e.g., Calderini 2008; Esponda 2004, 2004; Mouton 1997; Pallot 1997), this study focuses on the historical dimension of RC usage in Turkey and describes the technical, legal, and social contexts in which RC began being used in historic buildings. Specific cases of RC interventions in historic masonry structures in Turkey are investigated and a comprehensive framework is provided for understanding the concept of strengthening interventions in the context of RC usage, earthquakes, codes, and conservation theories by tracing the use of RC from the Ottoman era to the early years of the Republic of Turkey. The study ends with a brief review of the last century of RC usage in Turkey and future challenges facing Turkish conservation efforts.

1.1. Chronological and geographical settings of the research

This study covers the period from the introduction of RC to its conscious use in strengthening and consolidation, spanning from the late Ottoman era to the early years of the Turkish Republic (see Supplementary Figure S2 for an introductory outline of RC usage in this time period). The Ottoman Empire had grappled with internal conflicts, territorial losses, and a declining centralised authority, in stark contrast to the rapid industrialisation, technological progress, and cultural advancement witnessed in Europe (Shaw and Shaw

1977). At the same time, many institutions rooted in the Ottoman classical era were transformed by modelling European developments and moving towards Westernisation. Codification, systematisation, and the regulation of changes were heavily influenced by French law. After its establishment in 1923, the young Turkish Republic continued that process of change, with particularly significant influence from Germany spanning broad fields including education, military, industry, and science. France remained important, however, and Ali Saim Ülgen (1913–1963), a prominent figure in Turkish conservation history, played a role in maintaining France as a model in conservation in the Turkish Republic. He worked in the Directorate General of Antiquities and Museums, with responsibility for conserving heritage in a manner similar to that of France, and he significantly shaped the methodology of interventions to monuments with RC in Turkey beginning in the 1940s. For that reason, the time period of this study extends into the 1950s to capture Ülgen's influence in the early Republic period.

In the conservation realm, the regulatory and institutional frameworks implemented in Ottoman times were again heavily influenced by French models. However, given Turkey's historical origins and seismic characteristics, Italy was also an appropriate choice in establishing links and drawing parallels in the field of architectural conservation. Thus, this study briefly considers relevant historical developments in both of these countries. Shedding light on similarities to earlier practices observed in France and Italy will support the attempt to understand the processes involved in consolidation and conservation work in Turkey.

2. Technical context of RC usage in Turkey

2.1. Reinforced concrete in the education system

Reflecting the extent of European influence in the Ottoman Empire, the engineering school curriculum in Turkey at the beginning of the 20th century included intensive French education as well as vocational courses from its very first years. In this environment, it was inevitable that the use of RC would be transferred from Europe. The curriculum incorporated many textbooks on RC commonly utilised in Europe (Kaçar et al. 2012; Uzun 2008). According to records from the School of Engineering (*Mühendishane-i Berri-i Hümayun*, where the first civil architects and engineers were trained, later experiencing changes of name and affiliation to become *Hendese-i Mülkiye Mektebi*, then *Mühendis Mektebi*, and today Istanbul Technical University; Özcan and Kuban 2023), from 1911 onwards, many courses addressed this topic, such as the 'Reinforced Concrete' course of Mehmet Galip, a graduate of *École des Ponts et Chaussées* in Paris (Figure 1). The professors of the School of Engineering also continued working in the field and were members of architecture and engineering societies; thus, RC theory was carried to worksites, and the first graduates of the school became important state technical staff (Ergin 1941, 1041; Yavuz 2015). The Ottoman Society of Engineers and Architects, to which many School of Engineering professors belonged, had direct relationships with state institutions (Günergun 1987, 175).

The use of RC was also taught in architecture curricula. *Sanâyi-i Nefîse Mektebi* was the first Turkish art and architecture school, founded on the model of *Ecole Des Beaux-Art*; it was renamed as the Academy of Fine Arts in 1928. In this school, architects underwent extensive engineering training, equipping them with the ability to independently calculate when the use of RC was required on construction sites (Kafescioğlu 2019, 19). Many lecture notes on RC from that period still exist today, as well as records of the calculations of Ali Saim Ülgen and Cahide Tamer from the Academy of Fine Arts, before they achieved fame in the field of conservation (Figure 2).

2.2. Reinforced concrete in construction practice

The Messina earthquake of 1908 in Italy was a pivotal event in European technical history (Bertolaso et al. 2008). Occurring at a time of advanced engineering knowledge and the emergence of RC constructions, it prompted a significant shift in building practices and led to the widespread adoption of RC in reconstruction efforts for safer structures. This seismic event also catalysed the development of the first Italian seismic regulations (see Supplementary Figure S3), which emphasised the importance of framed structures and endorsed RC as a key material for earthquake-resistant designs (Calderini 2008, 28).

The use of RC in construction practices in Turkey was shaped by different cultural dynamics, resulting in different outcomes. Although Turkey is also located in a region of high seismic risk, regulations as extensive as those passed in Italy after the Messina earthquake did not materialise rapidly in Turkey. There are several reasons for this. Turkish culture has been described as fatalistic; instead of efforts to learn from past earthquakes, fatalism prevailed and earthquakes were viewed as an unchangeable and unfightable phenomenon (Mazlum 2011). Ottoman archival records contain many statements about earthquakes occurring by the order of God (Mazlum 2001; Satılmış 2019). On the other hand, as another type of catastrophic event, Istanbul was

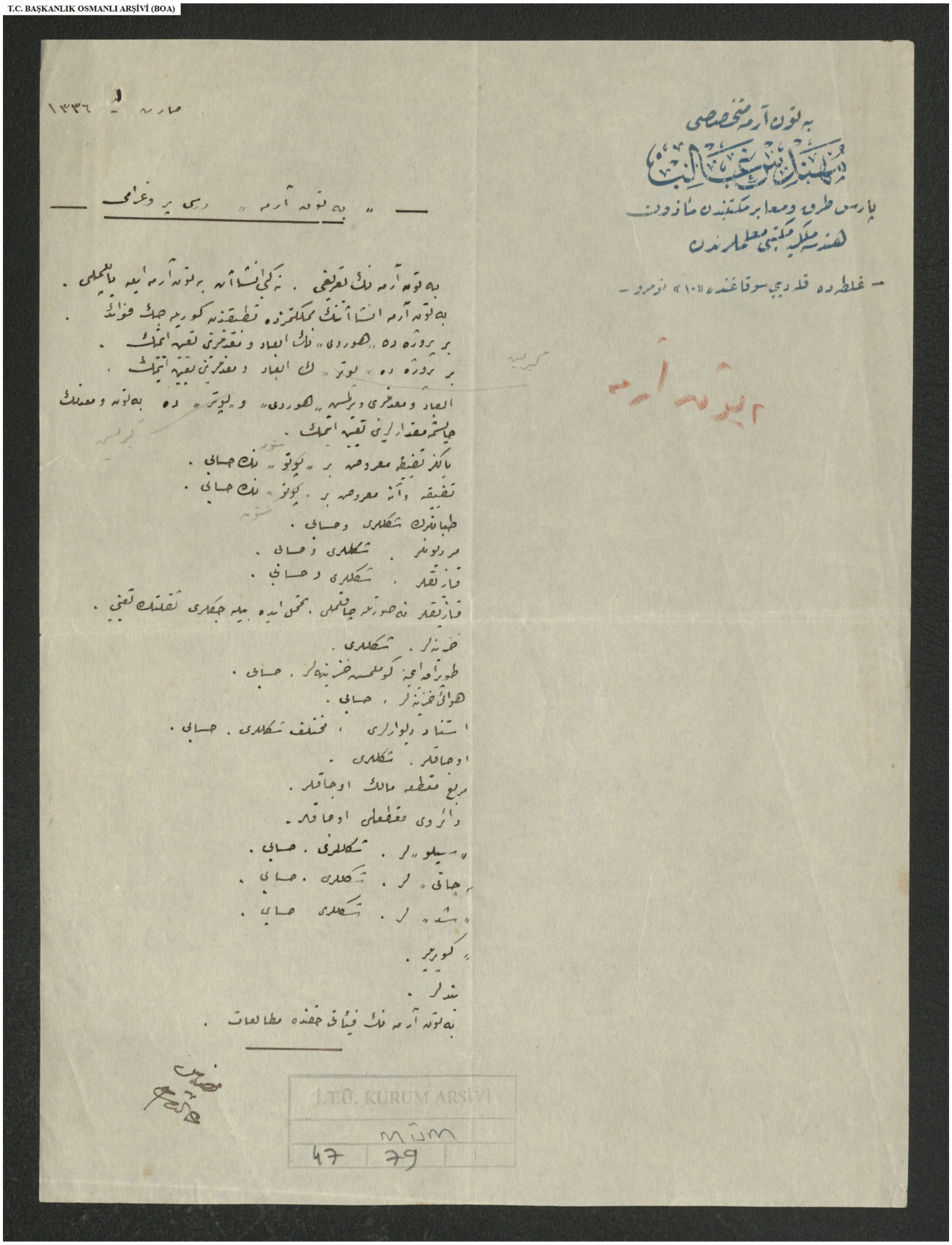

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Figure 1. 'Reinforced concrete' syllabus of Mehmet Galip, 1918.

suffering from and being transformed by fires from the early years of the nineteenth century. As that destruction coincided with the development of cement, Ottoman construction practices were adjusted to embrace cement and RC systems instead of wood, at least at the level of capital (Çelik and Deringil 2015, 64–108). Thus, even before the widespread strengthening of old Ottoman structures with RC began, RC was employed from the 1860s onwards in the construction of new buildings with municipal ordinances regulating and encouraging its use over traditional materials and techniques (Çelik and Deringil 2015, 76).

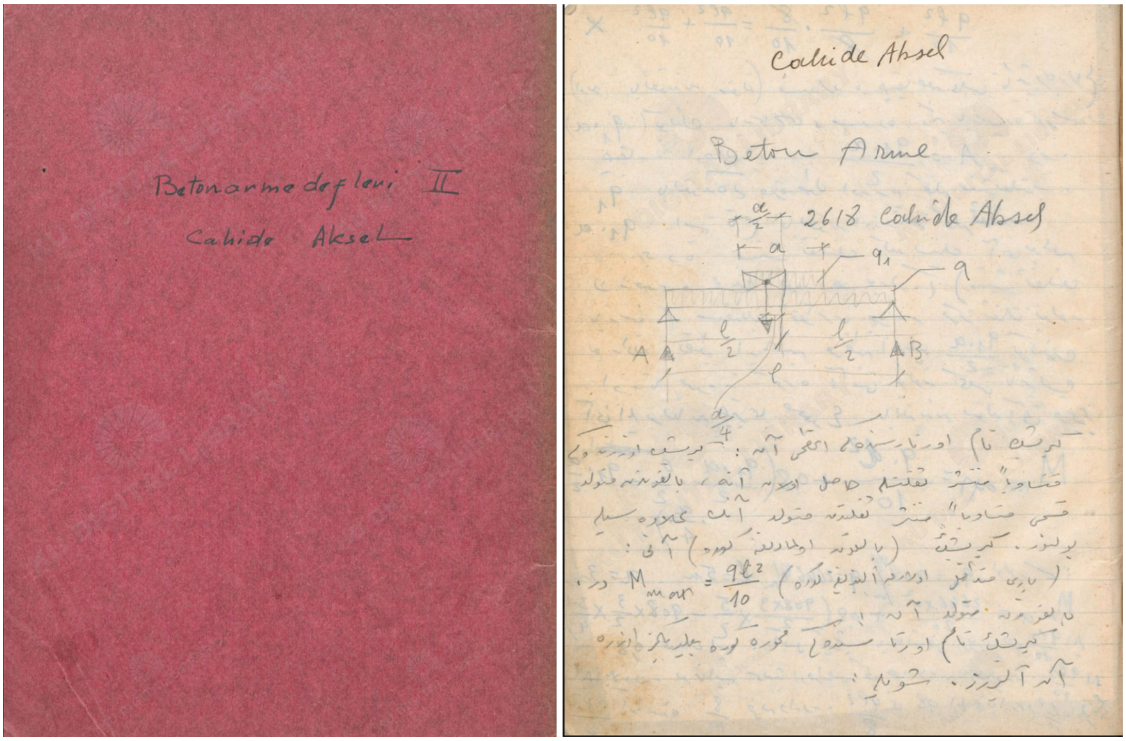


Figure 2. Notes of Cahide Tamer, who graduated from the department of architecture, academy of fine arts, in Istanbul in 1943 and worked for the state as a conservation architect, on the RC course she took as an undergraduate student (source: Cahide Tamer collection, 1938–1943).

2.2.1 Earthquake measures in Turkey and elsewhere

The 1908 Messina earthquake mentioned above was a landmark event for the development of novel materials and techniques to resist seismic forces with new building codes. The legal and technical advancements in Italy that followed the Messina earthquake can be compared to experiences in Istanbul in the same time period (Béton Armé Hennebique 1913a).

The Mürefte earthquake of 1912 occurred in the Marmara Region of Turkey with magnitude of 7.4. It offers fascinating insight into the Ottoman Turkish attitude towards earthquakes and that attitude's impact on the prevailing practices of construction to resist seismic forces. Military captain Dr. M. Sadi Bey, in his account of the Mürefte earthquake, described an intellectual tendency to neglect this significant event and a lack of relevant curiosity and research, patterns that he viewed as similar to those arising after the 1894 Istanbul earthquake. To address those deficiencies, he took it upon himself to document the earthquake of 1912 (Atabay and Borlat 2012, 40). He stated that the observatory in Istanbul lacked any documented records of the 1894 earthquake, despite its significant magnitude, estimated to have been 7.0. Considering the delayed establishment of that seismic observatory in Istanbul compared to other similar institutions of the time as well as its lack of the necessary equipment needed for optimal functioning, it can be inferred that the scientific understanding of earthquakes in the Ottoman Empire was limited. Furthermore, Dr. Sadi Bey also criticised the collapse of newly constructed public buildings in the earthquake. In addition to many mosques and clock towers, the Armenian Surp Takavor Church (1841) in Istanbul, the secondary school building (*kız rüşdiyesi*) (1882) in Tekirdağ, and the Gelibolu High School (*idadi*) Building (1886) and Gelibolu Government House (1864) were among the buildings that were severely damaged or destroyed (Arslan Çinko 2023, 132, 136, 236; Atabay and Borlat 2012, 62).

Various approaches can be observed in the repair or strengthening of monuments after these catastrophic events. For example, the Grand Bazaar, a significant historical landmark of Istanbul, underwent post-earthquake restoration following bids submitted by contractors. However, other important monuments were left in a state of disrepair for long Periods of time due to the high costs required for their restoration (Satılmış 2019, 197–217). The earthquake of 1912 did not lead to significant modifications in construction techniques or urban planning efforts. The most prominent damages were restored by returning structures to their pre-earthquake states using old practices.

The 1939 Erzincan earthquake had a higher magnitude of 7.8 and caused more extensive damage. Thus, it provided impetus for the development of a modern seismic code in Turkey. The relevant Italian code was directly translated and promulgated, and application efforts advanced as seismic events continued. The Turkish architectural journals of the time published discussions on methods of construction that would 'resist, prevent, or mitigate' earthquakes together with suggestions for changes in construction techniques and remarks on the necessity of using RC (Ünsal 1939).

2.2.2 Fire measures in Turkey

Perspectives on protective measures against fires differed notably compared to earthquakes as the issue of protecting traditional timber houses in Istanbul from fires was always on the agenda. Timber was an abundant and versatile construction material in this region, used not just for residential buildings but also in the construction of small-scale mosques. Interestingly, it has been suggested that the introduction of extensive wooden structures in Istanbul was initially a preventive action in response to the major earthquake of 1509 (Şahin Güçhan 2007). Regardless of the reason for its use, wood soon became a threat in the city, which struggled with fires. Urban fires had a profound impact on the built environment, prompting both changes in construction techniques and materials and the initiation of insurance studies and subsequent mapping efforts, such as the notable Pervititch and Goad maps (Ersoy and Anadol 2000). These maps clearly demonstrate the spread of RC in fire-affected areas (Figure 3).

Furthermore, the initial slogan adopted by the Bétons Armés Hennebique construction company, specialising in RC building processes, was *Plus d'incendies désastreux* or 'No more disastrous fires'. The seismic resistance of the Hennebique system, patented by French engineer François Hennebique in 1892, was included in promotional discourses following both earthquakes and fires (Béton Armé Hennebique 1913b, 1913c; Van de Voorde 2009). However, the Ottoman state could not give up the use of wood, even as it was rationalising systems against fires and creating new regulations. Timber remained an essential material through the end of the nineteenth century. It was preferred for most of the temporary houses of the Sultan and members of his court after the 1894 earthquake; only the facades were covered with English (Johnson) cement plaster to create the appearance of masonry (Acar and Mazlum 2016).

2.2.3 Hennebique in Istanbul and the spread of reinforced concrete

The establishment of the Hennebique Reinforced Concrete System in Istanbul played a pivotal role in the spread of RC in the Ottoman Empire, as it did worldwide. With that firm's influence, major applications of RC began in 1902 and grew in popularity until World War I. After 1910, RC applications constituted the main construction technique in Turkey (Karahan 2015). The first RC structure built in the Ottoman Empire was the Haydarpaşa Port Silo, constructed based on the Monier system in 1902, while Mesadet Han would be the first RC construction based on the Hennebique system in 1902–1904. RC was used in this period by public offices such as the Public Works, War, Education, and Foundations Ministries. In particular, in the Ministry of Foundations (renamed as the Directorate General of Foundations in the Republic period), renowned architect Kemaleddin Bey directed the Construction and Repair Science Board, which addressed both new constructions and the repair of monuments (Cengizkan 2009; Yavuz 2015). Kemaleddin Bey gained authority and respect with many crucial historic designs, such as the Karaağaç Railway Station of Edirne, an extraordinarily complex structure that exhibited both the power of engineering knowledge and aesthetics (Yavuz 2015, 15). Knowledge of RC was spread to the Ministry of Foundations largely thanks to him (Figure 4).

2.6. Specifications for reinforced concrete

In addition to curricula and textbooks for educational purposes, professional publications of RC specifications were issued after the Hennebique patent period. In 1932, a translation of German RC specifications was published by the School of Engineering (Löser and Gün [1932] 1941). Calculation methods and tables similarly based on German specifications were published in the following years. This decision to use the RC specifications of Germany, a country without significant earthquake experience, in Turkey, a country with zones of first-degree earthquake risk, was certainly a controversial choice.

Another country using the German technical legislation was Romania, which is also earthquake-prone. Due to a lack of significant earthquakes in the recent past, governmental technical standards and modern scientific considerations in seismic design were quite limited in Romania toward the beginning of the twentieth century, as in Turkey. Thus, the German technical legislation, which had widespread significant impact in the interwar period, was translated and published there (Vlad 2016,

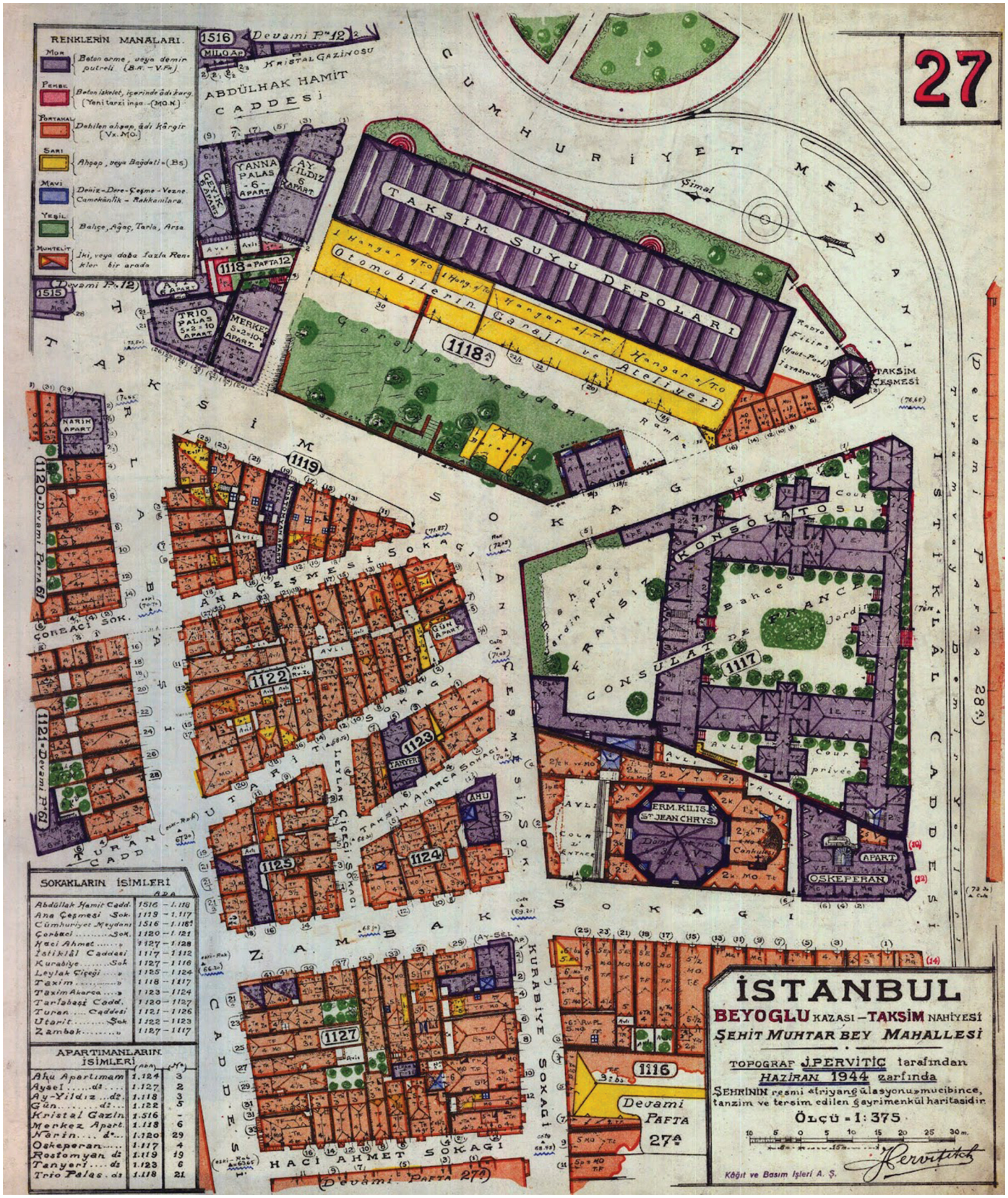


Figure 3. Pervititch insurance map, with legend designating construction techniques. Violet and pink colours indicate the use of RC (Ersoy and Anadol 2000).

113). However, Romania worked to address the lack of seismic considerations in the German specifications earlier than Turkey, after experiencing an earthquake in 1940. In the preface of his book about earthquake-resistant housing for Turkey, Kurt Bernhard, a German engineer working as a construction consultant and chief engineer in Turkey in the 1940s, confirmed that neither lateral thrusts due to earthquakes

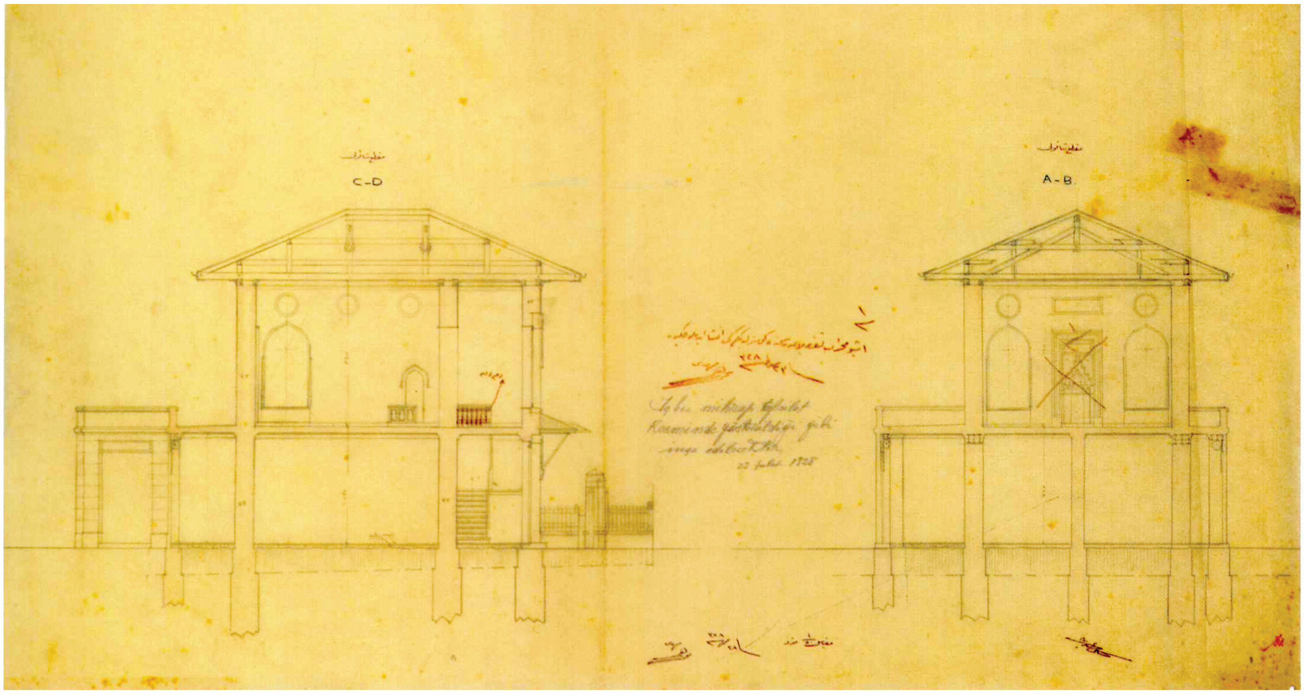


Figure 4. A project drawing made on a scale of 1/50 on 10 August 1912 by Kemaleddin Bey, including notes for a reinforced concrete slab (source: Batur 2009, 33).

nor wind were taken into account in the originally used RC calculations:

> Among colleagues, and especially among building contractors, there sometimes seems to be a hesitation to take earthquakes into account. This hesitation is partly due to psychological reasons, since these people had never experienced a severe earthquake before… So, they avoided the procedure at the expense of earthquake resistance for two reasons: they thought that it would be too laborious and costly, and they feared delays due to bureaucracy that would arise even when building a simple house. (Bernhard 1948, III)

3. Legal and social context for reinforced concrete in conservation efforts

In the nineteenth century, as conservation concepts began emerging in Europe, the issue of conservation entered the Ottoman agenda as well. New urban models were being implemented, but there was also interest in preserving historical buildings, which paved the way for the rise of conscious conservation. However, the legal regulations that can be defined as the first conservation code of the Ottoman Empire were focused not on monuments but on archaeological matters. The Ancient Monument Regulation (AMR; *Asar-ı Atika Nizamnamesi*) was first enacted in 1869 and addressed only archaeological artefacts (Madran 2002). The framework of the legislation would be expanded over the following decades, but it was only in 1906 that the definition of 'historic artefacts' was expanded to cover a wider range of historical buildings. However, the types of interventions to be applied were not specified in any detail (Şahin Güçhan and Kurul 2009).

Thus, the legal context for conservation was slow to develop, but the practical situation for conservation works was quite different. While traditional repair and maintenance practices continued, experts from Europe brought new perspectives and transferred conservation knowledge to colleagues in Turkey. Léon Parvillée, a pupil of Viollet-le-Duc, was tasked with restoring the *Yeşil Türbe*, or the mausoleum of Sultan Mehmed I, following the 1855 Bursa earthquake (Tekeli and Ilkin 1997, 21). Furthermore, the Green Mosque in Bursa, which suffered significant damage in the same earthquake, was repaired by installing iron hoops and pouring liquid cement into the cracked areas. With this approach, the cost of repairing the dome was reported to be less than anticipated (Ovalıoğlu et al. 2011, 357). The Fossati brothers, Raimondo D'Aronco, and other Levantine architects contributed to conservation efforts as well (Can 1993). Albert Gabriel undertook a study of Turkish art and architecture in Anatolia and later served as a conservation consultant for the Directorate General of Foundations in the 1930s (Erdur 2006).

RC became increasingly prevalent in construction during this era, but the first formal information on RC interventions in the field of conservation did not emerge until the 1930s. For example, in 1917, during the early phase of RC implementations in Turkey, Kemaleddin Bey addressed the strengthening and conservation of monuments without directly referring to the use of RC. He stressed that in the repair of historic buildings that have been destroyed by fires, earthquakes, or other disasters, in-depth examinations and consultations with commissions of science officers should be carried out. He focused on the necessity of authenticity, the preservation of original pieces, and the importance of avoiding architectural confusion for future research (Tekeli and Ilkin 1997, 20).

The final revision of the AMR continued being used in the Republic of Turkey until 1973, when the Republic's first new legislation on this issue was passed (Madran 2002). Scientific conservation activities were initiated in the 1930s, supported by the decision of Mustafa Kemal Atatürk, the Republic's founding father, to issue a telegram in 1931 warning about neglected and derelict monuments in Anatolia. The Council for Preservation of Monuments (*Anıtları Koruma Komisyonu*) was then quickly established under the Ministry of Education and an inventory of monuments with a list of priorities for preservation efforts was composed in 1933. The Ministry also worked to raise public awareness of conservation matters. Meanwhile, the section of the Directorate General of Foundations related to the repair of monuments was reshaped with new administrative duties and a new legal framework. In 1936, a book titled *Technical Specifications for the Repair and Construction of Mosques and Related Buildings* (*Camilerin ve Buna Şumuli Olan Binaların Tamir ve İnşalarına Ait Fenni Şartname*) was published (Vakıflar Umum Müdürlüğü 1936). It included decrees regarding the types of interventions to be performed in monument conservation as well as sections on RC interventions.

3.1. First official recognition of reinforced concrete interventions

Similar to the European context, where confidence in RC in restoration work was encouraged by the Athens Charter of 1931, Turkey witnessed official acceptance of RC in conservation in 1936 with the aforementioned publication of *Technical Specifications for the Repair and Construction of Mosques and Related Buildings* by the Directorate General of Foundations in cooperation with the Directorate General of Antiquities and Museums regarding technical approaches to monument conservation (Vakıflar Umum Müdürlüğü 1936). All RC interventions of any type that had been implemented prior to 1936 were formally recognised. Before these technical specifications, there had been no formal mention of RC interventions in conservation.

The new specifications addressed the principles and techniques of conservation efforts, identifying the scope of construction processes as either repairs or new construction/reconstruction. In both cases, it was advised to employ binders, plaster, or the injection of Portland cement and use locally sourced products of high quality. The need to preserve originality was emphasised, but it was made obvious that this concept also encompassed stylistic unity. Historical appearance and aesthetics were addressed without the notion of technical authenticity. In Article 8, valid reasons for reconstructing components with RC while maintaining the integrity of the original composition were defined. Where strength was required, cement mortar would be used in the repair of arches, walls, vaults, domes, and similar structures, which were previously treated with horasan plaster or lime. In particular, for components such as floorings, ceilings, and eaves, where the use of wood was not deemed structurally advantageous, there was a clear tendency of substituting them with RC to enhance structural efficiency.

These specifications were followed by related statements from Albert Gabriel, a consultant at the Directorate General of Foundations, in 1938. He explained that the use of cement in the restoration of medieval monuments should be strictly forbidden or at least must be avoided in the visible parts of the structures. The use of RC would be acceptable for the repair of a damaged dome structure or for purposes of support and strengthening. In such cases, however, the interventions should be fully exposed to reveal their age and relevance (Gabriel 1938, 12).

3.2. Ali Saim ülgen's discourse on reinforced concrete and the influence of France

Ali Saim Ülgen, one of the most important figures in the history of conservation in Turkey, began significantly impacting the methodology of interventions to monuments using RC in the 1940s. Before becoming Chief Architect of the Directorate General of Foundations, he observed the use of concrete while working in Europe. He collected examples of how RC was used there and how it was applied (Ahunbay 2016; Ülgen 1943), and he implemented RC interventions in several of the projects that he managed in Turkey (İnan Ocak 2018).

Ülgen was a conservation architect with a special interest in Viollet-le-Duc, referring to him as the 'distinguished chief architect'. In *The Conservation and Repair of Monuments* (Ülgen 1943), the first book published in Turkey on conservation, he highlighted the restoration efforts in France by allocating greater attention to them compared to those of other countries. He significantly described iron and RC as 'new materials used to provide monuments with greater stability and strength', and he explained the history of RC in France (Ülgen 1943, 50). He noted that its application was not yet widespread in Turkey and he cited cases of its use in Europe.

His book presented both benefits and drawbacks of RC interventions. He first incorporated European data on the disadvantages of changing traditional construction techniques. While new methods may be ideal for modern buildings, he stated, they are not appropriate for restoring historical buildings. He gave cases of the adverse effects of using cement, alum, and tar on the domes and drums of monuments instead of coating them with lead. He criticised RC material for its rigidity and said that its colour is incompatible with the elegant aesthetic of stone. Thus, it should not be utilised thoughtlessly as it does not contribute to the stone's external appearance.

Conversely, he clarified that cement could be injected into mortar that has suffered a loss in binding capabilities. Moreover, he encouraged the implementation of RC structural components or the implementation of a new skeleton for a weakened foundation, arch, or wall vulnerable to degradation. He included drawings and photographs from a repair project for the Church of St. Leon and the strengthening of the base under a column for a Roman theatre in Nimes together with a section drawing and a note of 'concealed reinforced concrete lintel' (Ülgen 1943, XXXII) (Figure 5). He also addressed an intervention to the foundation of the Souvigny Priory church, where the base was underpinned with the placement of a base of RC supported by tie rods (Deshoulières 1933, 484) (Figure 6).

He described the use of RC instead of wood for roofs, a common intervention in France, as a positive development in the context of the difficulty of finding wood and its vulnerability to fire. He praised the use of RC for offering the possibility of roofs with large spans that are lightweight, fireproof, strong, practical, and long-lasting. As examples of such use of RC, he cited restorations of the Soissons Cathedral and the Basilica of Saint-Remi (Ülgen 1943). He mentioned countries other than France more briefly, and no examples of RC interventions in Italy were given.

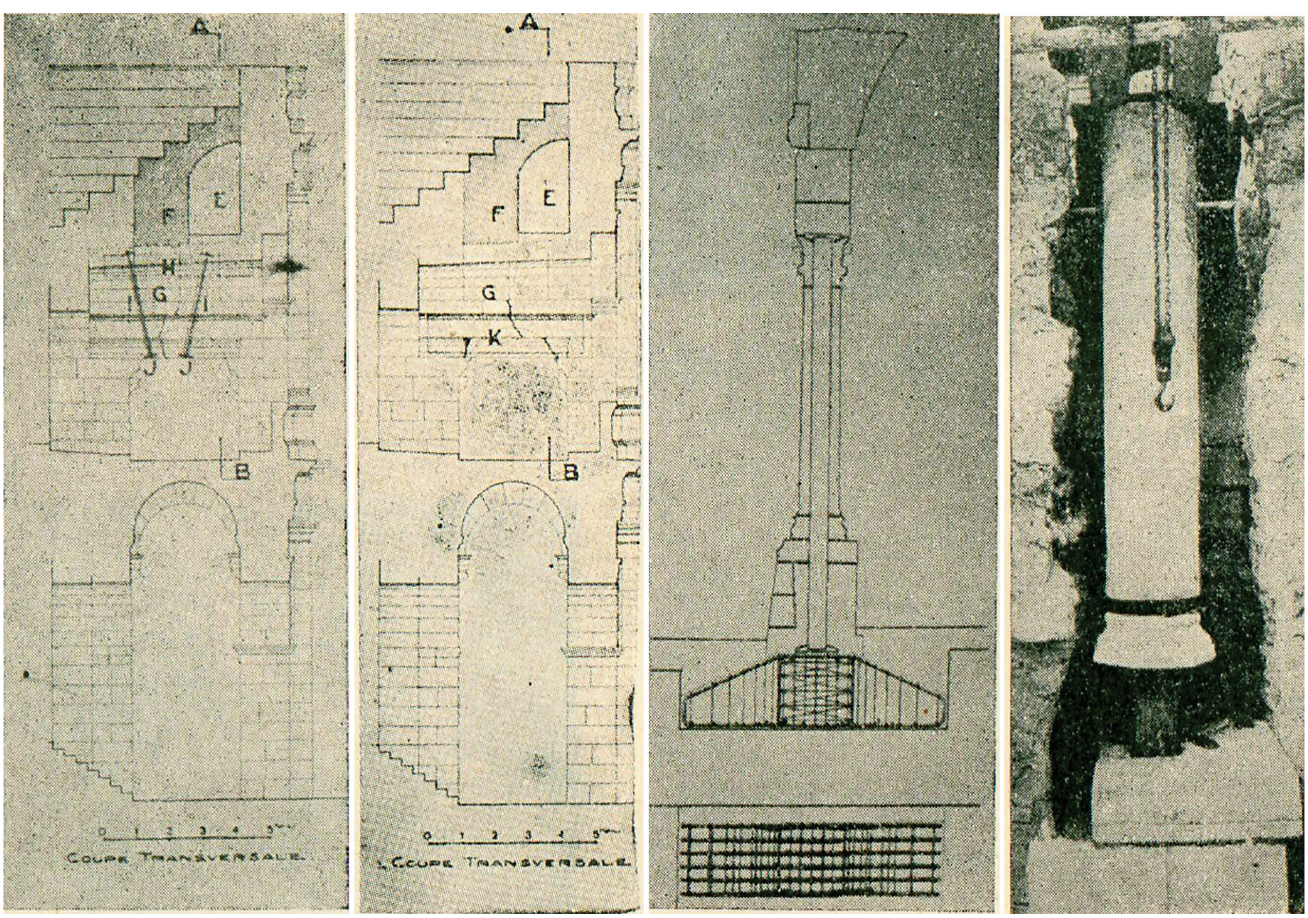


Figure 5. Examples of RC in historic masonry structure from Ülgen's (1943, XXXII).

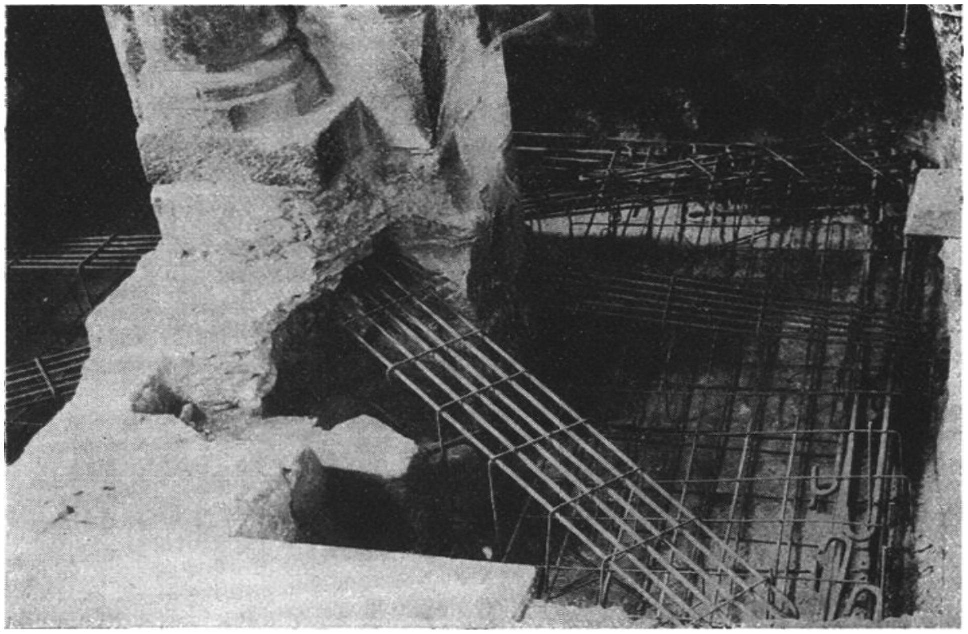


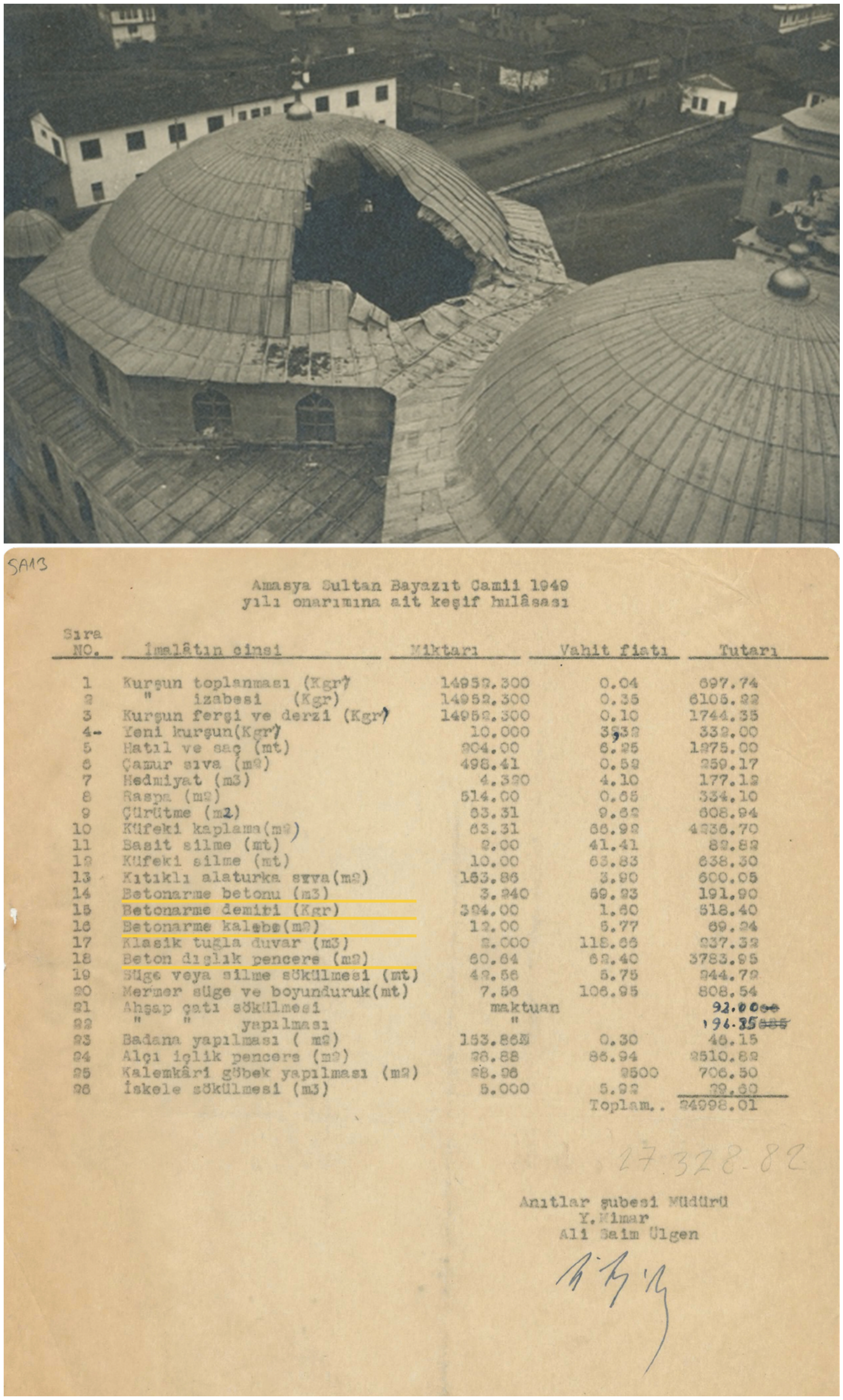
Figure 6. RC intervention to the foundation of the souvigny priory church, which Ülgen (1943, XXXII) also included in his book (Deshoulières 1933, 483).

As evidence of the scientific acceptance of RC in the conservation field, Ülgen described the necessary technical calculations for RC and how documents about these applications should be prepared and included in files on buildings to be restored. He asserted that survey work should not ignore technical calculations, such as those for RC, which are essential for restoration work. He provided examples of RC interventions from Turkey and France to illustrate this point. One was a project completed by Paquet, entailing RC interventions in the Church of Saint-Leu-d'Esserent, with Ülgen referencing Paquet's original publication. A second example was the concrete formwork and calculation project for the RC intervention to the historic Çifte Minareli Madrasah in Erzurum, Turkey (Ülgen 1943, 77, 80). Many tender specifications signed by Ülgen included clauses on RC interventions in the restoration of monuments (Figure 7). In addition, Ülgen's article titled 'Principles of Preservation and Restoration of Monuments', prepared in 1948 but only published after his death, described in detail the issues that should be taken into consideration in these applications, such as preparing mortar with cement and repairing cracks (Ülgen 1974).

4. Evaluation of cases

Turning from the historical framework for the adoption of RC to specific cases of its use (Figure 8), we see that cement was used for mortar and plaster in the Ottoman Empire immediately after its introduction to the construction industry. Many repair documents from the 1880s note the use of cement (Ekim 2018). The 1912 earthquake caused damage to some structures in Topkapı Palace and cement mortar was used in the repairs. For example, cracks in the domes of the Harem Lodge were repaired with cement (Coşkun 2012, 264). However, less information was recorded about the widespread use of cement as plaster. Detecting it on buildings is also difficult.

Calderini (2008), 34) proposed the following classification of RC interventions: 1) use of concrete as a binder; 2) use of RC to increase the resistant sections of structural elements and give them resistance to traction; 3) use of RC to create elements resistant to traction; and 4) use of RC for the building of new load-bearing structures inside masonry. It is obvious that these techniques have all been applied in Turkey. However, compared to the use of concrete as a binder, the deliberate use of RC to strengthen historic structures took more time to spread. The state of a structure and its architectural and technical characteristics also play roles in the choice of a particular technique. The most common applications have included converting flat timber floors into RC, constructing small-scale domes utilising RC, and using RC to reinforce two-layered conical domes. During the period in question, RC was extensively employed in the reconstruction of domes with small spans. As a more rare example from this period, the dome of Balipaşa Mosque, a central dome with a span of



SA13

Amasya Sultan Bayazıt Camii 1949
yılı onarımına ait keşif hulâsası

Sıra NO.	İmalâtın cinsi	Miktarı	Vahit fiatı	Tutarı
1	Kurşun toplanması (Kgr)	14952.300	0.04	597.74
2	" izabesi (Kgr)	14952.300	0.35	6105.22
3	Kurşun ferşi ve derzi (Kgr)	14952.300	0.10	1744.35
4-	Yeni kurşun(Kgr)	10.000	3,32	332.00
5	Hatıl ve saç (mt)	204.00	6.25	1275.00
6	Çamur sıva (m2)	498.41	0.52	259.17
7	Hedmiyat (m3)	4.320	4.10	177.12
8	Raspa (m2)	514.00	0.65	334.10
9	Çürütme (m2)	63.31	9.62	608.94
10	Küfeki kaplama(m2)	63.31	66.92	4236.70
11	Basit silme (mt)	2.00	41.41	82.82
12	Küfeki silme (mt)	10.00	63.83	638.30
13	Kıtıklı alaturka sıva(m2)	153.86	3.90	600.05
14	Betonarme betonu (m3)	3.240	59.23	191.90
15	Betonarme demiri (Kgr)	324.00	1.60	518.40
16	Betonarme kalıbı(m2)	12.00	5.77	69.24
17	Klasik tuğla duvar (m3)	2.000	118.66	237.32
18	Beton dışlık pencere (m2)	60.64	62.40	3783.95
19	Süge veya silme sökülmesi (mt)	42.56	5.75	244.72
20	Mermer süge ve boyunduruk(mt)	7.56	106.95	808.54
21	Ahşap çatı sökülmesi	maktuan		92.00
22	" " yapılması	"		196.35
23	Badana yapılması (m2)	153.86	0.30	46.15
24	Alçı içlik pencere (m2)	28.88	86.94	2510.82
25	Kalemkâri göbek yapılması (m2)	28.26	2500	706.50
26	İskele sökülmesi (m3)	5.000	5.92	29.60
			Toplam..	24998.01

27.328.82

Anıtlar şubesi Müdürü
Y. Mimar
Ali Saim Ülgen

Figure 7. Document related to the repair of Sultan Bayazıt Mosque in Amasya, 1949, following an earthquake, with concrete-related purchases underlined in yellow (source: Ali Saim Ülgen Archive, Salt Research 1949).

approximately 12 metres, was reconstructed with RC between 1933 and 1939 (Figure 9).

From the beginning, RC was used in the construction of new buildings as well as for strengthening existing masonry structures, albeit in smaller numbers (Karahan 2018). For example, in 1912 on Yüksek Kaldırım Street in Istanbul, the brick piers in the columned courtyard of a building, which is now an office block but was originally a residence, were retrofitted with RC. This intervention was carried out due to the building's changing loads

Figure 8. Intervention of RC dome with span of about 12 metres applied between 1933 and 1939 for Istanbul's Balipaşa Mosque, an example of a sixteenth-century monument (source: Vakıflar Umum Müdürlüğü n.d.).

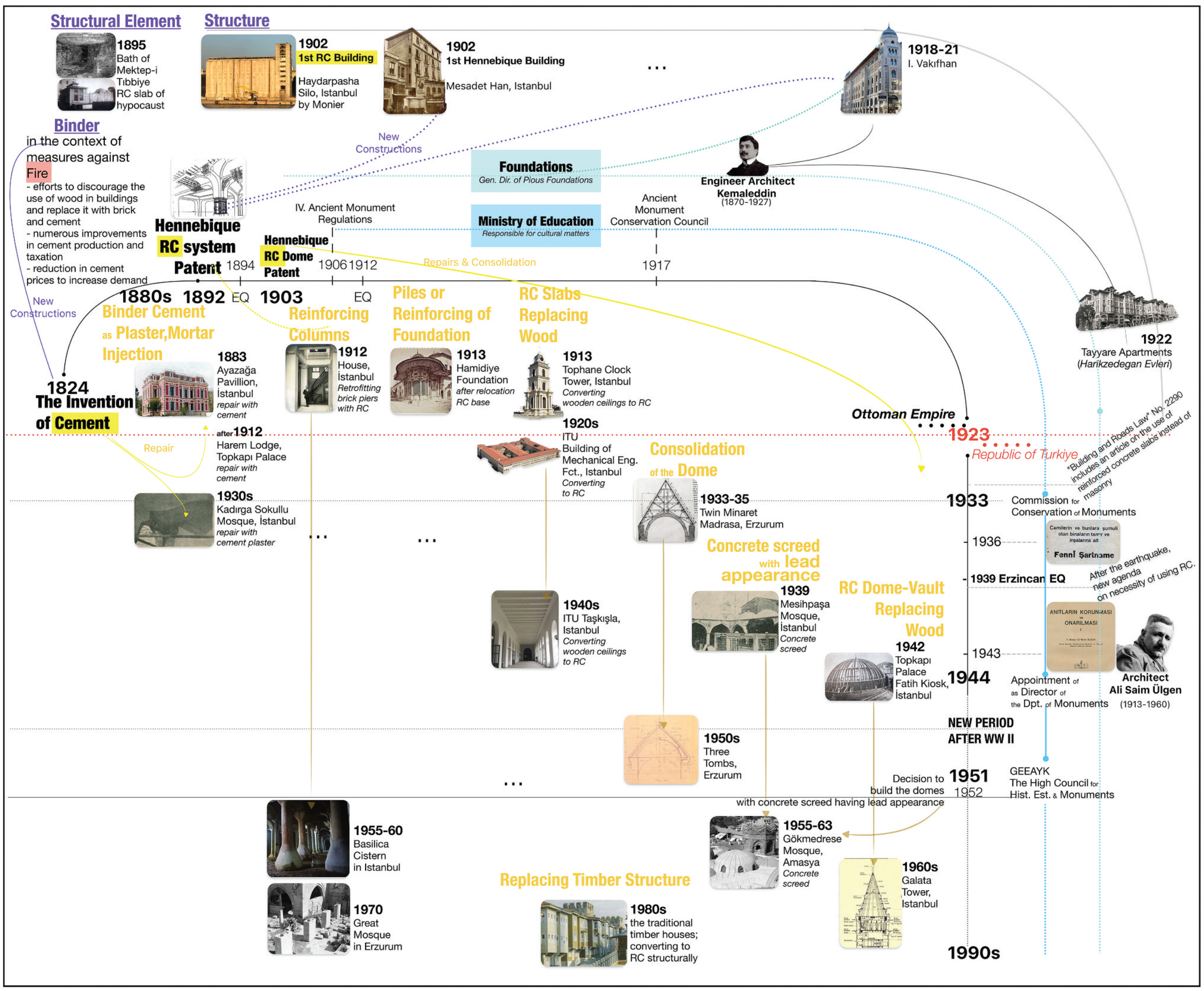


Figure 9. Significant cases of reinforced concrete interventions.

and it significantly increased the strength at the support points (Karahan 2018, 102). Karahan (2018) also documented the historical intervention to the Şehzadebaşı Madrasah, which was designed as a masonry structure but repaired with a slab of RC. For the Istanbul Tophane Clock Tower, after a fire in 1913 and problems with the structure leaning, the floor slabs were converted to RC (Çiftçi 2004). One of the most interesting applications using the Hennebique system was undertaken for the Hamidiye Sebili public fountain (Béton Armé

Hennebique 1913b). It was moved from its original location and rebuilt in a new place to allow the construction of the 4th Vakıf Han office building. During this relocation in 1912, the masonry structure was reconstructed on a new RC foundation. According to the fourth revised AMR, the fountain was to be considered a 'historic artefact'. However, moving a monument and not maintaining its original material was not even a matter of discussion in conservation at the time. This case highlights the fact that the AMR did not include any references to such interventions; it was limited to defining historic structures. Interestingly, when the fountain underwent another intervention in later years, its eaves, dome, and transitions to the dome were treated with RC once again.

4.1. Common techniques

4.1.1. CConverting wooden floors to reinforced concrete

RC was most often used to replace original wooden structural elements. Although these interventions were executed for structural strength, they can also be evaluated within the scope of the reintegration of wooden elements that disappeared over time or were thought to be weak. According to Pallot (1997, 53), these interventions, commonly seen in France, can be defined as 'substitution', or the replacement of a faulty or missing element by another of a different nature.

Similar practices were carried out for many buildings with masonry walls and timber floors and ceilings, especially those built in the nineteenth century. The current building of Istanbul Technical University's Faculty of Mechanical Engineering was renovated to meet spatial needs before it was allocated as an engineering school in 1929. Even before that, many of its timber ceilings had been converted to RC in the 1920s (Uluçay and Kartekin 1958, 598–599). At Taşkışla, which was a military building during the Ottoman period and converted into Istanbul Technical University's Faculty of Architecture in 1944, wooden elements were similarly replaced with RC in the transformation process (Figure 10).

4.1.2. Reinforced concrete domes

After World War I, the Hennebique system's prevalence declined and its patent eventually expired, but many

Figure 10. Substitution of wooden elements with reinforced concrete at Taşkışla, an Ottoman military building converted to the faculty of architecture of istanbul technical university in 1944 (source: encümen archive file No. 1107, Istanbul regional board of conservation of cultural heritage [Istanbul technical university faculty of architecture Taşkışla building]).

techniques had been learned thanks to Hennebique, including those for RC applications. For example, in 1903, Hennebique agents had introduced RC concrete domes as a new structural element. In Turkey, this type of dome was prominent among leading interventions of the twentieth century (Figure 11).

RC domes were utilised in particular for the inner domes of the two-layer superstructures frequently encountered in medieval constructions in both Anatolia and Transcaucasia. These interventions, in which the outer layer was not visible, were consistent with the principle of concealing RC that would be embraced in the following decades (Figure 12). The Twin Minarets (*Çifte Minareli*) Madrasah in Erzurum is of considerable importance as it reflects the deliberate utilisation of RC for consolidation. During restoration spanning from 1933 to 1935, the conical dome of the madrasah underwent a dismantling process and a novel RC structural system was constructed within the dome's inner layer, which was subsequently covered with stone. This restoration exemplifies the application of conservation principles and methodologies in the 1930s as a significant turning point in the conservation history of Turkey.

RC was also used in wooden domes and vaults, similarly to wooden slabs. Due to wood's vulnerability to fire and the fact that it was considered an expensive material with limited availability, it was largely replaced by RC. The Fatih Mansion of Topkapı Palace underwent a crucial restoration involving significant changes in the 1940s (Figure 13 and 14). The ceilings, known to have been originally wooden but renewed many times over the centuries, were converted to RC. Similar interventions to the wooden domes were undertaken at the same time (Öz 1991, 51; Tanyeli 1990, 186). In

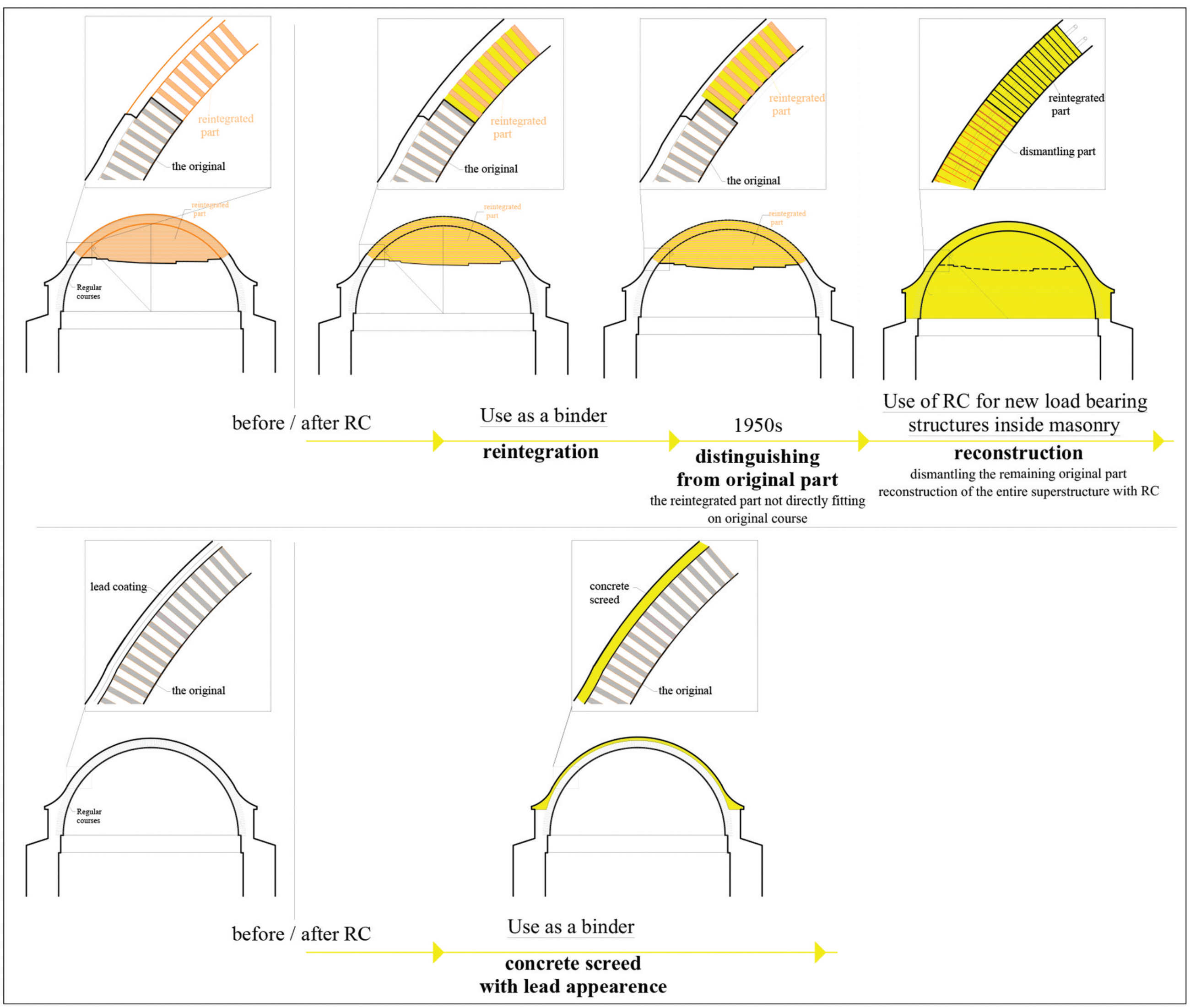


Figure 11. Variations of interventions to superstructures over time (source: Inan Ocak and Calderini 2023).

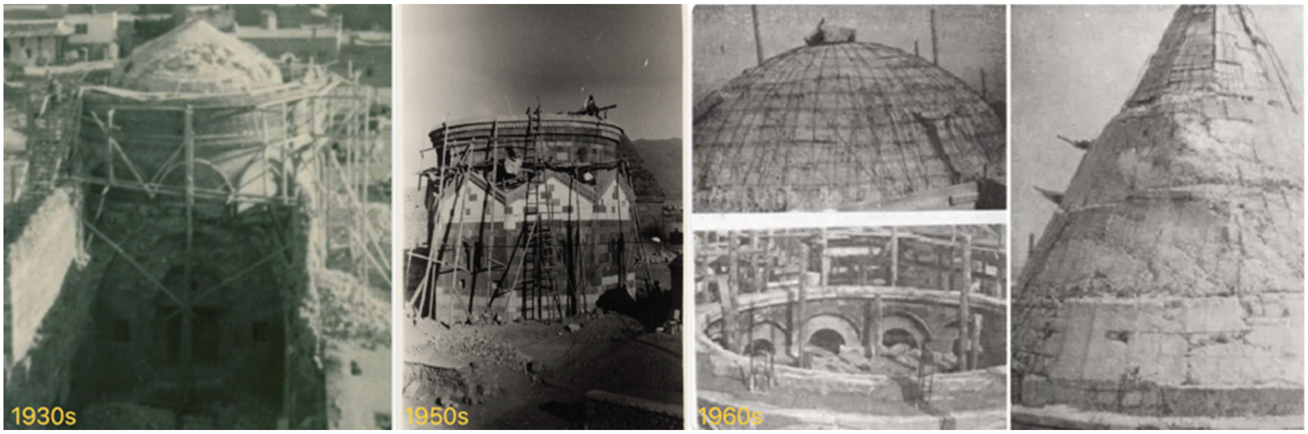


Figure 12. Reinforced concrete interventions on conical domes: Erzurum's twin minarets madrasah (source: Ali Saim Ülgen Archive, Salt Research 1933–35), Erzurum's tomb of Emir Saltuk (source: Ali Saim Ülgen Archive, Salt Research n.d.a), and the yeghvard church in Yerevan, Armenia (source: Marouti 2018).

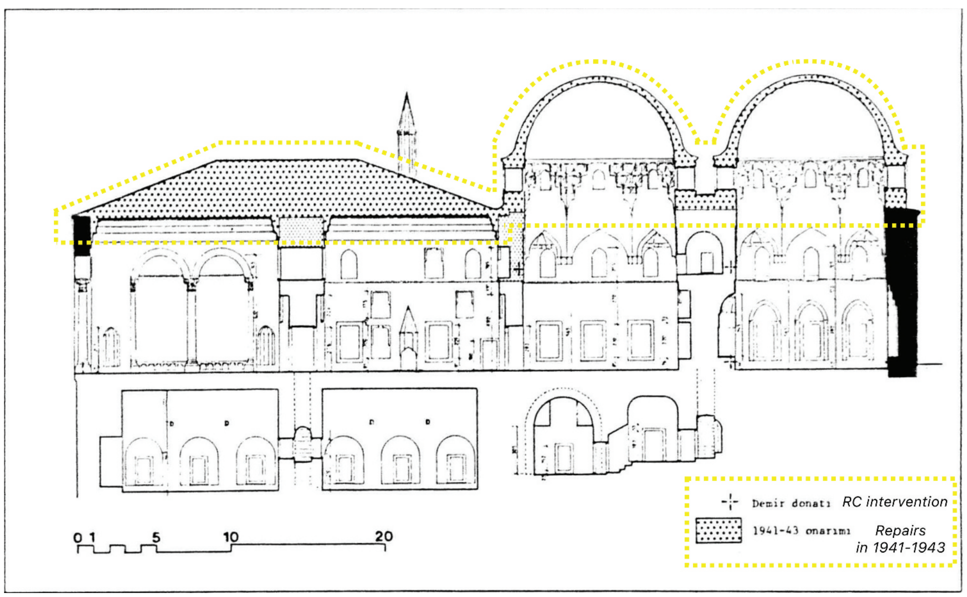


Figure 13. Topkapı palace, Fatih Mansion: RC interventions of 1941–1943 marked with yellow dashes (source: Tanyeli 1990, 192).

restoration works that started in 2019, the RC domes of the mansion were removed due to the heavy load on the structure and the cracks and sliding they had caused, and then it was aimed to restore the structure to its original Ottoman state.

4.2. Remarks on historic Periods of reinforced concrete interventions

4.2.1. Transition-I: forgetting traditional techniques and adopting reinforced concrete

The effective launch and widespread adoption of RC as a novel material in a region struggling with seismic activity and fires posed significant challenges due to the innovative nature of the material. Its utilisation in construction was a departure from traditional techniques, necessitating the acquisition of specialised knowledge and skills. This transition was full of unfamiliarity and obstacles, particularly for technical employees such as craftsmen and workers. Working with RC required structural analysis that could only be conducted by professionals in the fields of civil engineering and architecture, not by masons. Therefore, the use of RC faced opposition at the beginning (Tunc and Tunc 2022).

However, these difficult circumstances were effectively eased with the utilisation of combined RC and

Figure 14. Topkapı palace, Fatih Mansion: conversion of original timber dome to RC dome in 1942 and its dismantling in 2021 (sources: Öz 1991, 51 [top left]; Ergör and Benlioğlu 2021 [top right and bottom]).

masonry, referred to as a mixed system. In several structures, such as the Vakıf Hans of Istanbul, the edifice would exhibit a masonry appearance but RC parts would be structurally integrated into the masonry. The application of this type of construction could be described as a first phase of transition, during which expertise in the use of RC was acquired while traditional techniques were still being applied. In this context, interventions to monuments involving RC persisted into the following years as an extension of this transition while the predominant use of RC in the construction of new buildings was being witnessed (Figure 15).

Besides decisions in the field of conservation, laws and publications in various other fields also addressed the promotion of the use of RC. Law No. 2290 of 1933 on Buildings and Roads included an article on the use of RC slabs instead of masonry. After the major earthquake of 1939, construction techniques entered the agenda all the more. Architectural journals also published articles on the necessity of using RC. The 1949 Law on Public Hygiene prohibited the construction of adobe houses and included a clause discouraging the use of traditional materials and techniques. In other words, the use of RC in both new constructions and restorations was encouraged. Although they are listed as cultural property today, all traditional buildings beyond the scope of the conservation law at that time were also subject to interventions under this law as the conservation law encompassed only monumental buildings until the 1980s.

4.2.1 Transition-II: from consolidation to reintegration and even reconstruction

In the 1940s, Turkey experienced several devastating earthquakes that further structurally deteriorated already neglected and poorly maintained monuments (Ambraseys and Finkel 1995). With the dawn of conservation consciousness, restoration practices had begun in Turkey in the 1930s, but not all monuments were reached in time due to financial difficulties and a lack of experts. Despite the need for urgent repairs, many monuments were only restored for the first time in the 1950s after a long period of neglect. In further years, the increasing numbers of restorations of monuments led to rapid and unqualified work without the required historical research. Since the availability

Figure 15. Restoration of the grand mosque of Erzurum in the 1960s with stone masonry and RC techniques side by side (source: VGM archive, https://www.vgm.gov.tr/kurumsal/vakif-kayitlar-arsivi/vakif-kayitlar-arsivi).

of traditional materials was limited and it was not easy to find craftsmen, the use of cheap and easily applicable RC spread quickly.

4.4. Concerns about historical appearance and stylistic unity in the conservation field in Turkey

The transformation of practices that started with intentions of strengthening or repairing historical monuments into large-scale interventions that would become full reconstructions was shaped by deficiencies and confusion in the legal definitions. For example, in the technical specifications of 1936, it was recommended to utilise the same material as used in the original construction for dome repairs. Conversely, in cases where rebuilding was necessary, it was recommended to reconstruct the domes with RC in accordance with specified technical rules. According to the specification, an architect with conservation expertise would be given permission to repair a dome with its original material or to demolish it and rebuild it with RC. This was also valid for the wooden eaves (Figure 16). During this period, the given explanation lacked an explicit description of the specific circumstances under which the process of rebuilding was deemed necessary or not. It offered two different scale interventions as appropriate. That confusion led to a significant growth in reconstructions rather than the preservation of original components, causing the loss of traditional timber detailing and structures. In restorations of traditional timber houses in subsequent years, the cladding of facades with wood while the core structure was composed of RC can be interpreted as a result of the same perspective.

RC interventions have evolved in the direction of the concealment of the RC material. This has led to the emergence of reconstructions reminiscent of stylistic unity. In practices carried out in Turkey, a conservation approach in which historical appearance and aesthetic concerns are emphasised can be explicitly read (Coşkun 2018; Gençer and Çokuğraş 2023).

5. Conclusion: a century of reinforced concrete

The use of RC in conservation efforts marked a significant milestone as it surpassed a century, although it is still considerably younger than the monuments it seeks to preserve. Moreover, despite controversy, it remains a staple in conservation works. Certain critical stages have occurred along the path to RC taking its place in the field of conservation. Initially, in the practice of mixed buildings, some structural elements were designed as RC but the buildings were made to look like masonry. Given the challenges of concealing RC, as indicated in the 1931 Athens Charter, increasing practicality paved the way for the strengthening and repair of monuments. The practice of using RC in combination with masonry was a transitional process in which two different

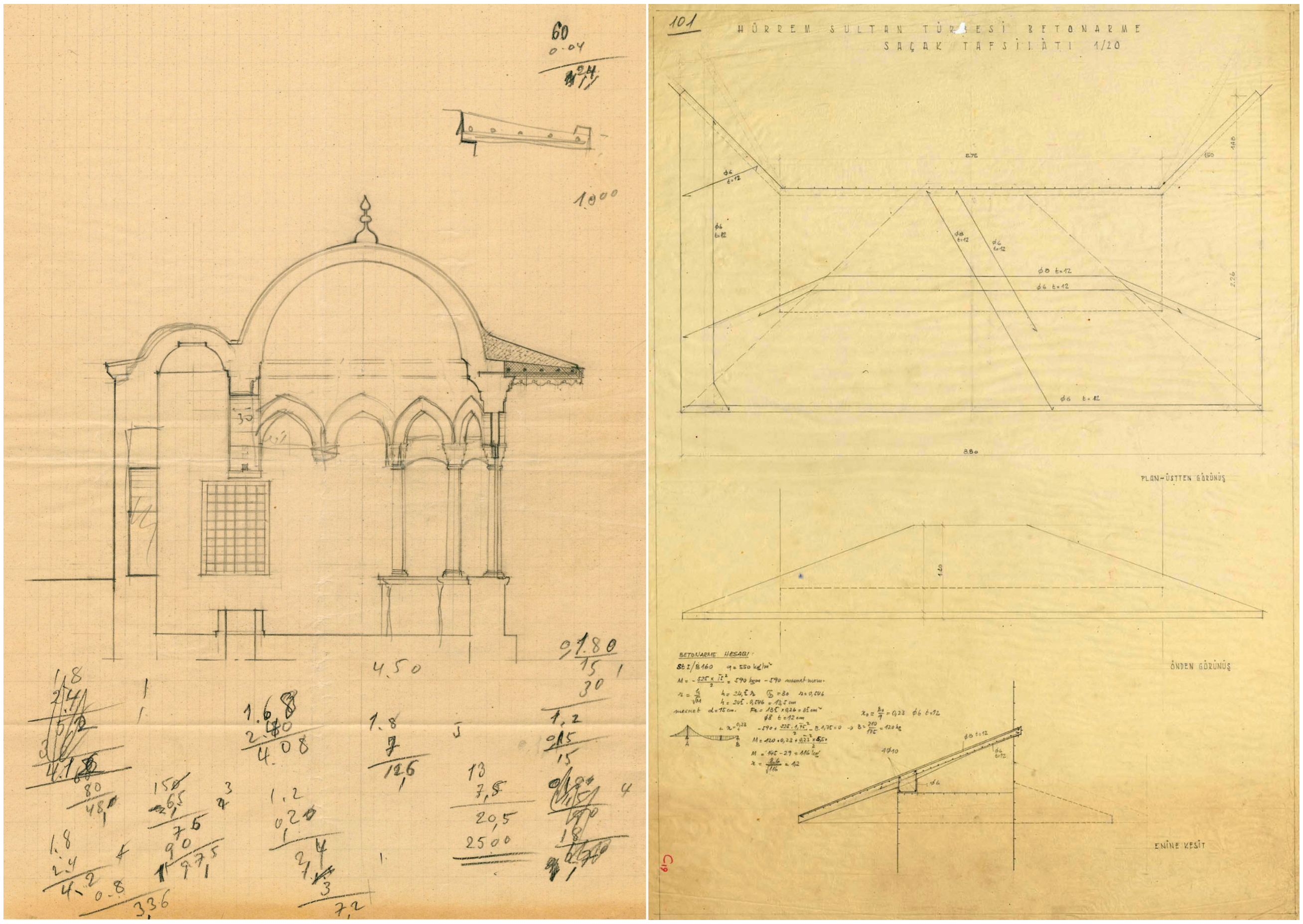


Figure 16. Examples of eaves constructed with reinforced concrete: Ibrahim Paşa Fountain (source: Ali Saim Ülgen Archive, Salt Research 1943) and Hürrem Sultan tomb with reinforced concrete canopy detail (source: Ali Saim Ülgen Archive, Salt Research n.d.-b).

techniques were tested together. In the second stage, the standards and patents of firms like Hennebique shaped the design of RC structural elements, enabling new uses. This constituted the transfer of European practices and knowledge to Turkey, not only of RC as a material but also in terms of processes from manufacturing to application. The application of RC to masonry structures also found a meaningful place in the history of civil engineering and the consolidation of monuments. Crucially, the spread of these interventions can also be attributed to the gradual abandonment of wooden construction techniques following fires, resulting in a decline in their usage and eventual oblivion. This shift in preference was accompanied by a growing reliance on RC and the widespread recognition of its superiority over alternative materials, particularly wood. The loss of wood and its construction techniques made it easier for RC to fill the void.

The processes of RC interventions in Turkey resemble those observed in France, where interventions predominantly involved substituting wooden elements with RC. This similarity may be viewed as inevitable in the field of conservation, considering that the Ottoman Empire underwent extensive institutionalisation influenced by the French in the nineteenth century. On the other hand, considering Turkey's historical origins and seismic characteristics, Italy is a more appropriate choice for drawing international connections in the field of architectural conservation. After the major Erzincan earthquake of 1939, Turkey's first earthquake regulation was produced based on the Italian code. However, there are no new earthquake regulations for historic buildings. Turkey's current earthquake regulations state that historical buildings are beyond their scope, while the 2017 Guidelines on the Management of Earthquake Risks for Historic Buildings prepared by the Directorate General of Foundations have not yet entered full force (Vakıflar Genel Müdürlüğü 2017).

More than a century has passed since the introduction of RC for interventions to monuments, but studies of the structural behaviours of traditional buildings still need to be undertaken with care. Apart from the question of RC, the reinforcement of masonry structures is still controversial. Although they do not meet the safety levels defined for new buildings today, monuments have survived over the centuries. The inadequate prioritisation of conservation efforts and the absence of a collaborative interdisciplinary culture among professionals, specifically engineers and architects, exacerbate the difficulties presented by the frequent occurrence of earthquakes in Turkey. Moreover, due to the disorganised approach to conservation in the early period and the delayed appearance of any formal specifications not only for the use of RC in repairing historic buildings (Vakıflar Umum Müdürlüğü 1936) but also for restoration techniques in general, RC applications were utilised with relatively haphazard criteria for decades. With the spread of RC in the field of conservation over time, structural assessment has become challenging for historic masonry structures, which are deteriorating as a result of salt crystallisation due to cement and are shaped by two different construction techniques having different structural behaviours. Thus, many early interventions to historic monuments pose challenges to conservationists and decision-makers today. At the intersection of engineering and architecture, there is a need for a focused approach to RC interventions to historic buildings, specifically addressing structural concerns.

Considering that the main problem from a practical perspective is to assess the effectiveness of masonry and RC systems, engineers adopting conservation consciousness and engaging in meaningful dialogue with conservation architects will be crucial in scientific conservation works. However, when aiming to return heritage buildings to their authentic states, architects must first valorise later additions to the structure and RC interventions in particular. It is advisable to minimise the unnecessary dismantling of RC without structural reasons simply to pursue ‘stylistic unity’; RC interventions should be respected as integral historic components of monuments. Retaining these interventions to historic structures whose original geometry is now uncertain can prevent falsification and provide a more neutral state. RC interventions have played crucial roles in ensuring the survival of monuments to the present day and the recognition of historical interventions can be ensured by clearly distinguishing RC from the original character of a structure. The concept of ‘stylistic unity’ emphasised in the past was considered an acceptable criterion for the conditions of those days. However, in contemporary Turkey, decisions to remove RC interventions without structural assessments are contrary to modern international conservation principles.

Consequently, in deciding how to move forward with the preservation of Turkey’s historical monuments and how to approach interventions done in the past, RC interventions to historic structures should not be evaluated based on only authenticity while also emphasising that dramatic interventions should be avoided. Superficial evaluations based on a single viewpoint, without scientific evidence, must be rejected, such as definitive claims that previous RC interventions should or should not be dismantled. To conduct an accurate assessment of any case, it is essential to gain deep knowledge of the structure and to examine the historical background of the RC interventions. Each case must be considered on its own merits.

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