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CARBONATION OF CONCRETE: HISTORICAL DEVELOPMENT AND CHANGING INTERPRETATIONS

KARBONATYZACJA BETONU: ROZWÓJ HISTORYCZNY I ZMIENIAJĄCE SIĘ INTERPRETACJE

Maciej Lech*
Kielce University of Technology, Poland

Abstract

Carbonation of cement-based materials has been interpreted in different ways during the development of building materials and concrete technology. This paper presents a selective narrative review of the main milestones that changed the meaning of carbonation: from the useful hardening of lime binders, through the durability problem of reinforced concrete, to present discussions on blended and low-clinker binders, accelerated testing and CO₂ uptake. The review was based on historically important, methodologically relevant and currently influential literature. Particular attention was paid to the changing interpretation of carbonation in relation to binder composition, exposure conditions, reinforcement corrosion, testing methodology and the growing use of supplementary cementitious materials. The review shows that carbonation cannot be treated as a single, universal durability indicator. Its meaning depends on the type of binder, moisture conditions, pore structure, alkaline reserve, presence of reinforcement and the aim of assessment. The main conclusion is that concepts developed for ordinary Portland cement systems cannot be directly transferred to concretes rich in supplementary cementitious materials without additional interpretation and method-specific validation.

Keywords: carbonation, accelerated carbonation, concrete durability, reinforced concrete, supplementary cementitious materials, CO₂ uptake

Streszczenie

Karbonatyzacja materiałów na bazie cementu była różnie interpretowana na kolejnych etapach rozwoju materiałów budowlanych i technologii betonu. W artykule przedstawiono selektywny przegląd narracyjny najważniejszych kamieni milowych, które zmieniały znaczenie karbonatyzacji: od korzystnego twardnienia spoiw wapiennych, przez problem trwałości żelbetu, aż po współczesne dyskusje dotyczące spoiw mieszanych i niskoklinkierowych, badań przyspieszonych oraz pochłaniania CO₂. Przegląd oparto na literaturze o znaczeniu historycznym, metodologicznym i współczesnym. Szczególną uwagę zwrócono na zmieniającą się interpretację karbonatyzacji w odniesieniu do składu spoiwa, warunków ekspozycji, korozji zbrojenia, metod badawczych oraz rosnącego stosowania dodatkowych materiałów cementowych. Przegląd pokazuje, że karbonatyzacja nie może być traktowana jako jeden uniwersalny wskaźnik trwałości. Jej znaczenie zależy od rodzaju spoiwa, warunków wilgotnościowych, struktury porów, rezerwy alkalicznej, obecności zbrojenia oraz celu oceny. Główny wniosek jest taki, że pojęć wypracowanych dla układów opartych na cemencie portlandzkim nie można bezpośrednio przenosić na betony bogate w dodatkowe materiały cementowe bez dodatkowej interpretacji i walidacji właściwej dla danej metody badawczej.

Słowa kluczowe: karbonatyzacja; karbonatyzacja przyspieszona; trwałość betonu; żelbet; dodatkowe materiały cementowe; pochłanianie CO₂

1. INTRODUCTION

Carbonation has long been recognized as a key mechanism of hardening in lime binders exposed to atmospheric CO₂ [1]. In modern concrete technology, however, the same process is discussed mainly in the context of durability and reinforcement protection [1-9]. This change in meaning makes carbonation a useful subject for a review that connects the history of materials with current research on durability. The paper assumes that the interpretation of carbonation changed over time together with the development of binders, structural systems and durability criteria.

In lime-based systems, carbonation was a useful phenomenon. In Portland cement systems, it entered the field of cement chemistry. In reinforced concrete, it became linked with steel depassivation and the risk of corrosion. Modern low-clinker systems require a further reinterpretation, because carbonation resistance, corrosion behaviour and CO₂ uptake can no longer be discussed only on the basis of ordinary Portland cement (OPC) [2, 5-8].

Instead of covering all published studies on carbonation, this paper presents a selective historical synthesis focused on the main stages, key authors and changes in the basic research questions. This approach may be useful for readers interested not only in what is known about carbonation, but also in how and why its meaning changed with the development of concrete science, as summarized in Table 1.

2. REVIEW METHODOLOGY AND SCOPE OF THE PAPER

This paper was prepared as a selective narrative review. Its aim was to reconstruct the main stages in the development of knowledge on carbonation and to follow the changes in its scientific and engineering interpretation. The literature was collected by targeted searches in Scopus, Web of Science and Google Scholar from January 2024 to March 2026. The following search terms were used: carbonation, cementitious materials, durability, reinforcement corrosion, accelerated carbonation, natural carbonation, supplementary cementitious materials, blended cements and CO₂ uptake. To improve the completeness of the search, backward and forward citation searching, review of reference lists and consultation of standard historical and technical works often cited in this field were also used [1-8, 10, 11, 14, 16-22].

The collected material was assessed in relation to the aims of the article. The scope included the historical development of knowledge on carbonation from lime materials to reinforced concrete [1, 10, 11, 14-18], mechanistic explanations of the process

[2, 16, 21, 22], and its interpretation in relation to steel depassivation, corrosion risk and durability assessment [3, 4, 17-20]. The paper also includes current discussions on carbonation in blended and low-clinker systems, especially in relation to testing methodology and CO₂ uptake [2, 5-9, 12, 13].

The literature finally included in the paper was selected because of its relevance to the argument presented here and its ability to show wider changes in the understanding of carbonation. The aim was not to prepare a full list of all contributions to this field, but to indicate milestones showing important historical, methodological and interpretative changes [1, 2, 16-22]. Because this article is not a systematic review, no PRISMA diagram or bibliometric meta-analysis is presented. Nevertheless, the review was prepared with a clear scope, search logic, selection rules and limitations of the adopted approach.

3. BEFORE CARBONATION OF CONCRETE BECAME

A PROBLEM: LIME, MORTARS AND THE FIRST BUILDERS

Vitruvius [14] is probably the earliest written reference point for the historical understanding of building materials. His *De Architectura* (Ten Books on Architecture) documented Roman building knowledge in the first century BC. Although Vitruvius did not describe carbonation in the modern chemical sense, his treatise reflects an early stage in which lime materials were understood mainly through practice, empirical material selection and accumulated building experience.

Long before the development of cement chemistry, carbonation controlled the behaviour of air-hardening binders. Lime mortars gained strength through the reaction of calcium hydroxide with atmospheric carbon dioxide, which led to the formation of calcium carbonate [1, 10]. In such conditions, carbonation was not a defect or a durability threat. It was the basis of hardening.

This historical starting point shows that carbonation first appeared in building practice as a useful process. Pre-modern builders did not know the concepts of concrete cover, depassivation or durability design. Their main problem was whether the binder set, hardened and kept cohesion over time. The scientific language later used to describe carbonation did not yet exist, although its visible effects were well known in practice.

This long, pre-theoretical period is not only a simple introduction to concrete technology. It helps to explain why carbonation was later reinterpreted as a durability threat. The reaction itself was not new, but its engineering meaning changed together with the technological context. Figure 1 presents the historical background of

this change, including the move from empirical practice to more systematic knowledge about binders.

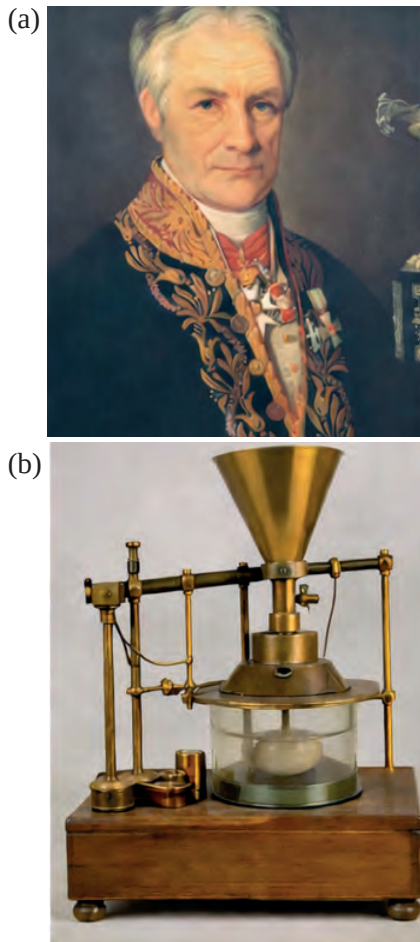


Fig. 1. (a) Louis Vicat (1786-1861), (b) Vicat apparatus. Source: portrait and apparatus image based on Wikipedia materials

4. FROM HYDRAULIC LIME TO PORTLAND CEMENT: LOUIS VICAT AND JOSEPH ASPDIN

Louis Vicat [10] (1786-1861) represents the transition from empirical practice to organized binder science. His work on hydraulic lime and the treatise connected with his name helped to organize knowledge about lime and hydraulic binders. It also created a language in which setting and hardening could be discussed more clearly. From this perspective, Vicat did not discover carbonation as a separate phenomenon, but he helped to create the intellectual basis that later allowed its mechanistic interpretation.

Joseph Aspdin [11] (1778-1855) represents another important change: the industrialization of binder production. His 1824 patent [11] for Portland cement is usually treated as a key starting point of the Portland cement era, as shown in Figure 2. From the viewpoint

of the history of carbonation, Aspdin is important not because his patent solved the carbonation problem, but because it opened the era of cementitious materials in which carbonation was later studied as a change in hydrated cement paste and finally as a durability problem of reinforced concrete.

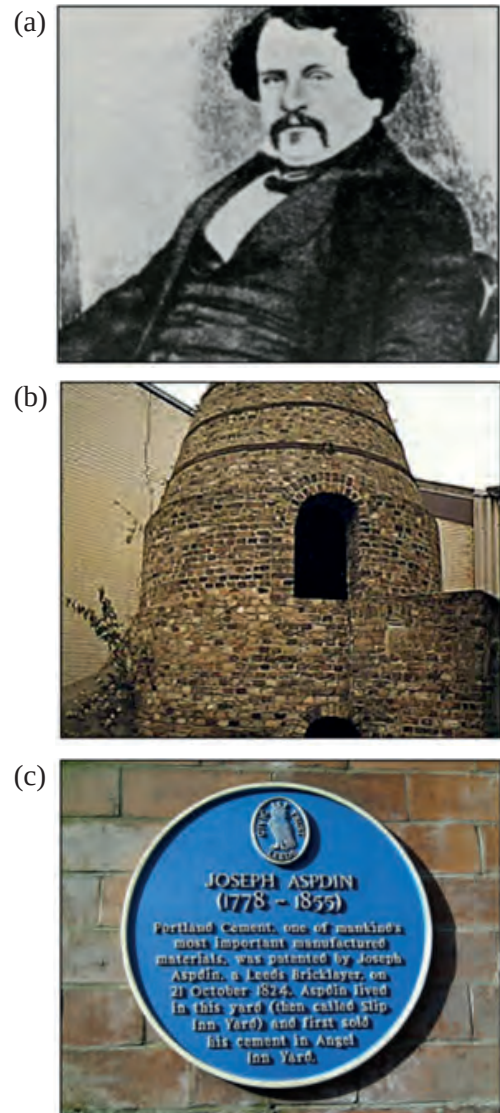


Fig. 2. Joseph Aspdin and selected historical references to the early Portland cement era: a) portrait attributed to Joseph Aspdin, b) preserved 19th-century bottle kiln associated with early cement production, c) Leeds Civic Trust plaque commemorating Aspdin's 1824 Portland cement patent. Source: author's compilation based on Wikimedia Commons and Cement Kilns documentation

Another important milestone of the nineteenth century was the work of Joseph Monier [15], a French gardener and inventor who patented iron-reinforced cement containers in 1867. Although Monier's

contribution was not directly related to the chemistry of carbonation, it marked the beginning of reinforced concrete as a new structural material. When steel was embedded in cementitious materials, carbonation gradually gained a new engineering meaning: it stopped being only a chemical change in the binder and became a process able to reduce alkalinity and influence reinforcement protection.

Together, Vicat and Aspdin mark the beginning of the nineteenth century as a key stage in which the scientific and industrial foundations of modern carbonation research were created. One symbolizes the scientific ordering of binder knowledge, and the other the beginning of an industrial family of materials in which carbonation later became an important long-term problem.

5. CARBONATION BECOMES A SCIENTIFIC AND ENGINEERING ISSUE: VERBECK AND HAMADA

In the twentieth century, carbonation stopped being only a practical observation and became a subject of cement chemistry. A key milestone was the classical work by Verbeck [16] on carbonation of hydrated

Portland cement, which organized the chemical changes connected with carbonation in hardened cement paste. Verbeck's contribution was important because it described carbonation as a transformation of specific hydration phases, not only as an external surface effect. The main chemical changes connected with this approach are shown schematically in Figure 3.

The next important step was to link carbonation with the behavior of reinforced concrete. Hamada's work [17] on neutralization of concrete and corrosion of reinforcing steel explained the engineering meaning of the decrease in alkalinity caused by carbonation. It is also one of the earliest widely cited works describing the use of phenolphthalein to identify the carbonated zone in concrete – a method that later became standard in carbonation assessment. This change connected carbonation with the loss of passive steel protection and helped to establish the classical durability approach in which carbonation is treated as a phenomenon preceding corrosion risk. The engineering meaning of this change, especially for reinforcement protection, is shown in Figure 4.

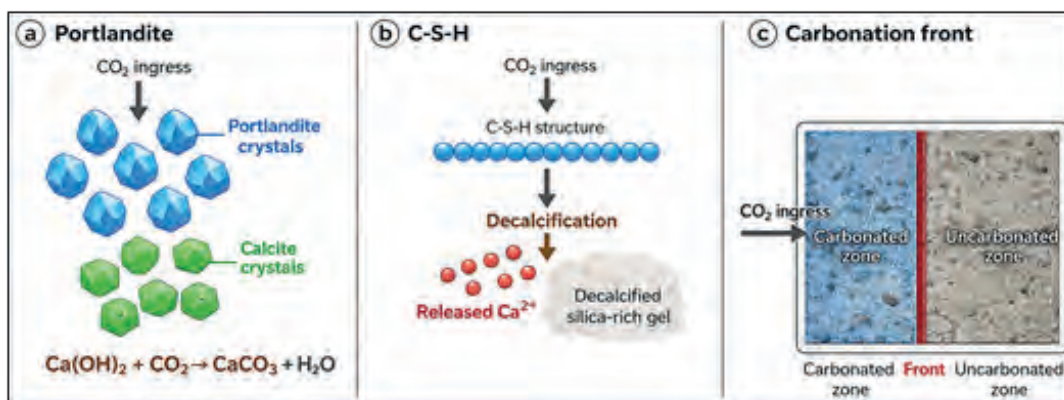


Fig. 3. Author's schematic illustration of carbonation chemistry based on Verbeck [16]: portlandite carbonation, decalcification of C-S-H and an idealised carbonation front in hardened cement paste

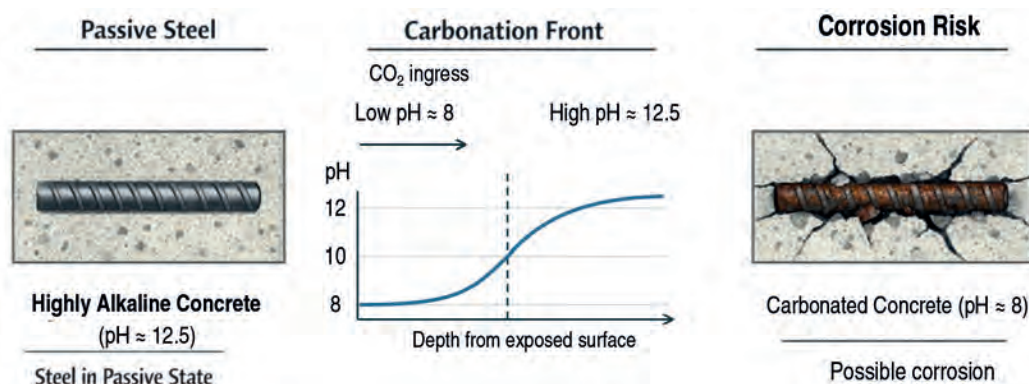


Fig. 4. Author's schematic interpretation based on Hamada [17]: CO_2 ingress, reduced alkalinity and risk of steel depassivation. The pH profile is illustrative; corrosion also depends on exposure conditions

At the same time, current literature clearly shows that the relation between carbonation and corrosion is not strictly deterministic. Carbonation may create a thermodynamic condition for depassivation, but the corrosion rate strongly depends on moisture, degree of pore saturation, oxygen transport and exposure conditions [3, 4]. For a historical review, this distinction is important because it separates the moment when the durability paradigm appeared from its later clarification.

6. CARBONATION AS A DURABILITY

AND DIAGNOSTIC CONCEPT: TUUTTI AND PARROTT

Kyösti Tuutti's 1982 dissertation *Corrosion of Steel in Concrete* [18] is one of the key texts of durability engineering because it included carbonation in the now classical model of initiation and propagation of steel corrosion in concrete. In this approach, carbonation became one of the main mechanisms able to end the initiation phase by lowering alkalinity at the reinforcement depth. The question was no

longer simply whether carbonation occurs, but when the carbonation front will reach the steel. Figure 5 schematically illustrates this durability concept.

Parrott [19, 20] developed this way of thinking towards diagnostics and assessment of real structures. In papers published in 1990 and 1994, he analyzed the relationship between carbonation depth, moisture condition, corrosion and the observed condition of reinforced concrete elements. His contribution is important because it moved carbonation research beyond an abstract mechanism and towards the practical assessment of existing structures. Figure 6 presents this diagnostic interpretation.

The Tuutti-Parrott stage marked the moment when carbonation was fully included in service-life thinking for structures. Modern syntheses also show that carbonated concrete must be assessed with attention to moisture exposure and transport conditions. Without this context, the simple equation $\text{carbonation} = \text{corrosion}$ becomes an excessive simplification [3, 4].

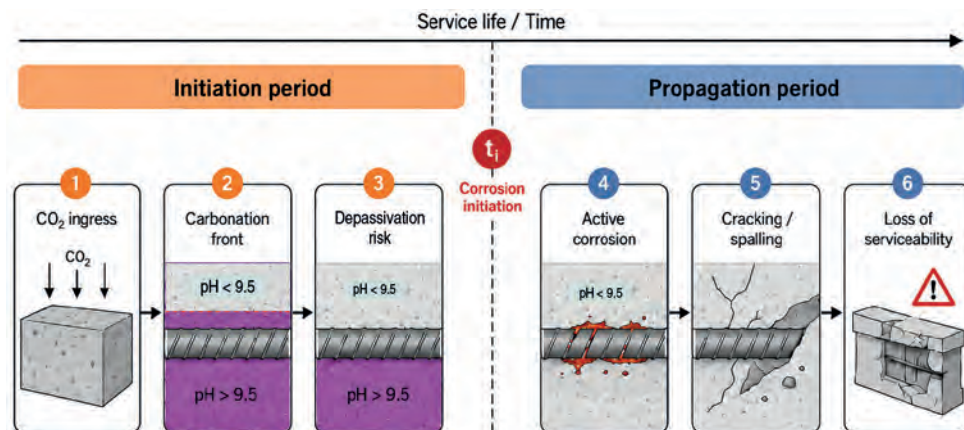


Fig. 5. Author's schematic illustration based on Tuutti's initiation-propagation concept [18]: carbonation, risk of depassivation, corrosion and possible subsequent damage. The pH values are indicative

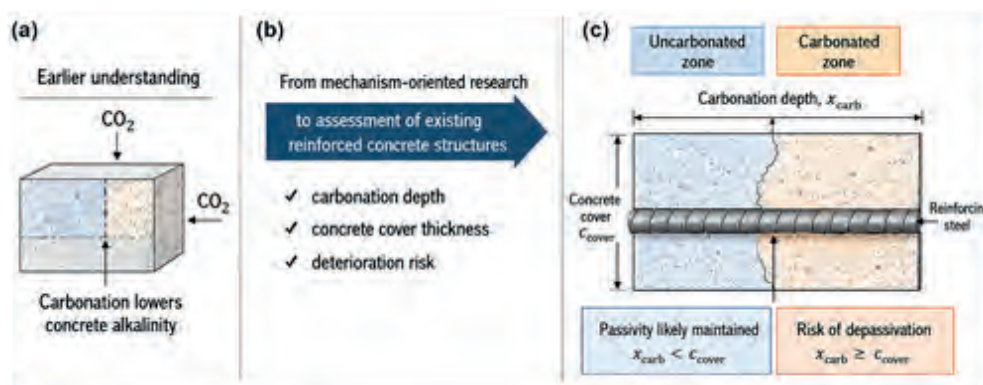


Fig. 6. Author's schematic diagnostic interpretation based on Parrott [19, 20]: carbonation depth relative to concrete cover. Assessment of corrosion risk also requires moisture and exposure conditions

7. FROM OBSERVATION TO MODELLING: PAPADAKIS AND THE MECHANISTIC TURN

Papadakis and co-workers [21, 22] gave carbonation research a mechanistic and predictive dimension by describing carbonation as a coupled transport–reaction process. In this approach, the progress of carbonation depends on CO_2 ingress through the pore system, its dissolution in the pore solution, reactions with portlandite and CSH in the cement paste, and the resulting movement of the carbonation front within a porous cementitious material. The moisture state plays a key role because it controls both CO_2 transport and the availability of pore solution for carbonation reactions. The main elements of this interpretation are presented schematically in Figure 7.

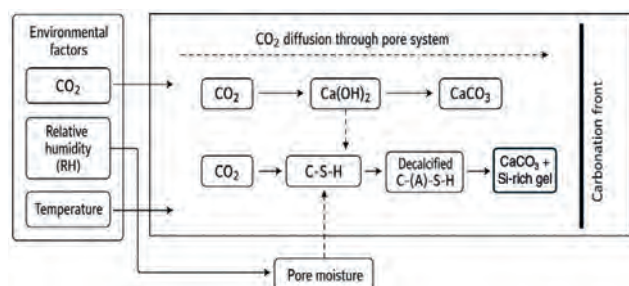


Fig. 7. Author's schematic interpretation based on Papadakis et al. [21, 22]: CO_2 transport, moisture and chemical reactions controlling the advance of an idealised carbonation front

This was an important conceptual advance because carbonation depth could then be treated not only as an empirical observation revealed by phenolphthalein, but also as the result of coupled physical and chemical processes. Binder composition, porosity, moisture content and reactive capacity became explicit variables of the analysis, not only background conditions.

The mechanistic turn remains central for modern modeling. It also explains why accelerated and natural carbonation cannot simply be treated as equivalent phenomena. When carbonation is understood as a coupled transport–reaction process, differences in CO_2 concentration, humidity, pre-conditioning and sample history become scientifically important and not only procedural [5-8, 22].

8. REINTERPRETATION IN THE ERA OF BLENDED AND LOW-EMISSION BINDERS

Modern research on carbonation is largely shaped by changes in cementitious systems themselves. The increasing use of supplementary cementitious materials (SCM) and low-clinker binders means

that conclusions formulated for Portland cement concretes cannot be automatically transferred to blended systems [2, 5-8]. Differences in the hydrate phase assemblage, pore solution chemistry, buffering capacity and pore structure affect both the kinetics of carbonation and the interpretation of test results.

In concretes containing high amounts of SCMs, carbonation may differ from ordinary Portland cement systems in several connected ways. First, the replacement of clinker usually reduces the amount of portlandite and changes the alkaline reserve of the binder. As a result, less CO_2 may be required to lower the pH, even if the measured carbonation depth does not fully describe the risk of corrosion. Second, the main hydrate assemblage changes. In slag, fly ash or other blended systems, C-S-H or C-A-S-H phases may have a lower Ca/Si ratio and may decalcify differently during carbonation. This affects not only the chemical buffering capacity but also the pore structure after carbonation. Third, SCMs often refine the pore structure when curing is sufficient, which may reduce transport, but insufficient curing or high replacement levels may increase carbonation rates because the chemical reserve is lower. Therefore, the carbonation resistance of SCM-rich concretes is controlled by a balance between transport properties and chemical buffering capacity.

This balance is one of the reasons why carbonation depth should not be interpreted in isolation. A larger carbonation depth in an SCM concrete does not always mean the same durability state as the same depth in an OPC concrete. The interpretation should also include moisture exposure, curing history, binder type, replacement level, pore solution chemistry and the presence or absence of reinforcement.

The critical review by RILEM TC 281-CCC [2] showed that carbonation of concretes with SCM is clearly different from carbonation of concretes based only on Portland cement, and that exposure conditions, curing history and SCM characteristics must be interpreted together. Later reports [5, 6] stressed important differences between standardised methods and showed that accelerated and natural carbonation results are not directly interchangeable without proper contextual correction. The 2025 closing letter of the committee [7] and the CPC-18R1 recommendation from 2026 [8] strengthened this conclusion by indicating still existing research needs and updating methodological guidelines for measuring carbonation depth with pH indicators. Figure 8 summarizes the current interpretation context of carbonation in concretes with SCM.

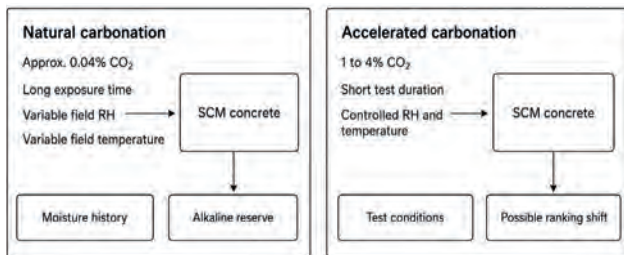


Fig. 8. Current interpretation context of carbonation in concretes containing supplementary cementitious materials (SCM), showing the influence of binder composition and the methodological differences between natural and accelerated exposure.

Source: own elaboration based on [2, 5-8]

The review by Bernal et al. [5] is especially useful here because it stressed the combined role of CO₂ concentration, relative humidity and CO₂ buffering capacity in carbonation tests. This observation helps to explain why the ranking of materials under accelerated exposure may differ from the ranking obtained under natural exposure, especially in blended systems.

8.1. Consequences for carbonation assessment methods

The reinterpretation of carbonation in SCM-rich concretes is closely connected with the method used for its assessment. The phenolphthalein test is simple, inexpensive and useful for determining the apparent carbonation depth. It is therefore suitable for routine comparison and for diagnostics of existing structures. Its limitation is that it identifies a pH-related boundary rather than the complete chemical progress of carbonation. In blended systems, where the pore solution chemistry and buffering capacity differ from OPC concretes, the colour change may not fully represent the degree of carbonation of individual hydrate phases or the actual corrosion risk.

Natural carbonation tests are more representative of field exposure because they use realistic CO₂ concentrations and moisture variations. However, they require long exposure times and their results are strongly affected by local climate, curing history and specimen pre-conditioning. Accelerated carbonation tests are much faster and useful for comparative assessment, but high CO₂ concentrations may change the balance between transport and reaction. This is particularly important for SCM-rich concretes, where the ranking of mixtures under accelerated exposure may differ from the ranking observed under natural conditions.

For this reason, accelerated tests should not be treated as a direct substitute for natural carbonation without validation. They are valuable for screening and

comparative studies, but service-life prediction and durability classification require careful interpretation. In concretes with high SCM contents, carbonation assessment should preferably combine carbonation depth with information on binder composition, curing, moisture state, pore structure and, where reinforcement is present, corrosion-relevant exposure conditions.

9. CARBONATION AS A DURABILITY THREAT AND AS CO₂ UPTAKE

In more recent literature, carbonation is interpreted in two connected but different perspectives. In studies on reinforced concrete, it remains mainly a durability issue because the decrease in alkalinity may lead to steel depassivation and increase the risk of reinforcement corrosion [3, 4]. In environmental studies, the same process is analyzed as a mechanism of CO₂ uptake by cementitious materials during service life, after demolition and during reuse [9, 12].

The importance of this second perspective is confirmed by global assessments. Xi et al. [9] estimated cumulative uptake at 4.5 Gt C in 1930-2013, which corresponds to about 16.5 Gt CO₂ and about 43% of cement process emissions in that period. Updated estimates [12] showed cumulative uptake of 23.89 Gt CO₂ in 1930-2023, equal to about 52.3% of cumulative cement process emissions in that period. Annual uptake reached 0.93 Gt CO₂/year in 2023. Experimental studies [13] also confirmed measurable CO₂ uptake in Portland cement pastes and blended cement pastes under controlled conditions.

It is therefore necessary to separate the scale and aim of assessment. At the structural scale, carbonation may be unfavourable if it leads to the loss of reinforcement protection. At the material, resource and life-cycle scale, it may at the same time be an element of the carbon balance. These perspectives are not contradictory, but they should not be mixed without a clear indication of whether the analysis concerns the durability of a reinforced concrete member, the behaviour of a material, or CO₂ uptake.

10. HISTORICAL SYNTHESIS, PRACTICAL IMPLICATIONS AND FINAL REMARKS

The milestones discussed above show that the history of carbonation is a history of changing research questions. For lime binders, the main questions concerned hardening and cohesion of the material. For Portland cement, the analysis moved towards the chemistry of hydrated paste.

The development of reinforced concrete shifted attention to alkalinity, steel depassivation and corrosion risk, while mechanistic modeling made it possible to describe carbonation as a transport-reaction process depending on binder composition, moisture, pore structure and exposure conditions [1-8, 21, 22]. Modern research on blended and low-clinker binders and on CO₂ uptake does not replace this interpretation, but extends it and requires more careful selection of test methods [2, 5-8, 9, 12, 13]. The main stages in the development of knowledge on carbonation are presented in Table 1.

Three practical consequences for current carbonation research follow from this synthesis. First, conclusions obtained for systems based only on ordinary Portland cement (OPC) should not be directly transferred to concretes with a high content

of supplementary cementitious materials (SCM), because buffering capacity, microstructure and pore solution chemistry change [2, 5, 6]. Second, carbonation depth alone is not a universal durability indicator. Its meaning depends on moisture, exposure class, binder composition, presence of reinforcement and conditions that promote or limit corrosion development [5-8]. Third, the test method should follow the aim of assessment. Service-life prediction, material comparison, diagnostics of existing structures and estimation of CO₂ uptake are all connected with carbonation, but they answer different questions and should not be interpreted by one simplified criterion [5-8, 12].

The ecological transformation of cementitious materials makes this problem more important. Low-emission and blended systems can no longer be

Table 1. Key stages in the development of knowledge on carbonation. Source: own elaboration based on [1-22]

Period / year	Researcher / concept	Main contribution	Importance for the development of knowledge on carbonation
1st century BC	Vitruvius	Early written synthesis of Roman knowledge on building materials, construction practice and durability in <i>De Architectura</i> .	The earliest textual reference point for the practical understanding of lime construction before modern cement chemistry.
Antiquity - 19th century	Lime binder	Carbonation understood in practice as the hardening mechanism of lime mortars exposed to atmospheric CO ₂ .	The earliest stage of understanding: high practical importance, but without formal cement chemistry.
1817-1818	Louis Vicat	Systematisation of knowledge on hydraulic lime and hydraulic binders.	Transition from craft knowledge to scientific description of binders.
1824	Joseph Aspdin	Patent for Portland cement and symbolic beginning of the industrial cement era.	Opening of a family of materials in which carbonation later became a durability problem.
1867	Joseph Monier	Patent for iron-reinforced cement containers and early development of reinforced concrete.	Beginning of the reinforced concrete era, in which carbonation was later directly linked with reinforcement protection and durability assessment.
1958	G.J. Verbeck	Systematic description of the chemistry of carbonation of hydrated Portland cement.	Carbonation became a cement chemistry issue, not only a practical observation.
1968	M. Hamada	Linking concrete neutralisation with loss of alkalinity and risk of reinforcement depassivation.	Carbonation gained a clear engineering meaning for reinforced concrete.
1982	Kyösti Tuutti	Inclusion of carbonation in the model of initiation and propagation of steel corrosion in concrete.	Carbonation became a key durability concept and a basis for service-life thinking.
1989-1991	V.G. Papadakis	Physicochemical modelling of carbonation as a coupled transport-reaction process.	Transition from empirical description to mechanistic and predictive analysis.
1990-1994	L.J. Parrott	Diagnostic interpretation of carbonation depth, moisture influence and damage assessment in existing structures.	Transition from the mechanism itself to diagnostics and condition assessment.
2020	Critical review by RILEM TC 281-CCC	Critical synthesis of carbonation of concrete with supplementary cementitious materials.	It showed that SCM-rich systems need a separate interpretation from OPC systems.
2016-2024	Xi et al.; Wu et al.; Andrade et al.	Quantitative determination of global CO ₂ uptake and experimental confirmation of carbon binding in cementitious systems.	Separation of carbonation as a durability threat from carbonation as a carbon uptake mechanism.
2024	Bernal et al.; Vollpracht et al.	Critical review of standardised test methods and database-based analysis of carbonation factors.	Indication of the limits of direct comparison between natural and accelerated carbonation and of the role of testing methodology.
2025-2026	De Belie and Bernal; CPC-18R1	Synthesis of research needs and updated recommendation for measuring carbonation depth using pH indicators.	Methodological consolidation and modern reinterpretation in low-emission systems.

interpreted only from the durability point of view. They should also be considered in relation to CO₂ uptake, testing methodology and the future development of material strategies based on a circular economy [9, 12, 13, 23-27]. These issues should be treated as an important direction of future carbonation research and not as a separate subject outside the main discussion on durability.

In modern concrete science, carbonation is placed at the intersection of durability, testing methodology and

environmental assessment. It is therefore no longer enough to consider only its influence on the service life of structures. Future research should also explain how carbonation can be interpreted and controlled in low-emission binders and recycled cementitious materials, without excessive simplification of their long-term performance assessment [2, 5-8, 9, 12, 13, 23-27].

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REVITALISED MARKET SQUARES OF SMALL TOWNS IN THE ŚWIĘTOKRZYSKIE REGION WITH FUTURE GENERATIONS IN MIND

ZREWITALIZOWANE RYNKI MAŁYCH MIAST W WOJEWÓDZTWIE ŚWIĘTOKRZYSKIM Z MYŚLĄ O PRZYSZŁYCH POKOLENIACH

Małgorzata Doroz-Turek*
Kielce University of Technology, Poland

Abstract

Revitalisation encompasses efforts aimed at resolving social, economic and spatial issues, particularly in smaller towns and cities, while also playing a vital role in preserving cultural heritage. The author presents this issue through the case studies of selected towns in the Świętokrzyskie region which date back to the Middle Ages, where local authorities employ revitalisation initiatives to restore them to their former glory and improve their usability. To achieve this, projects frequently leverage the towns' most valuable surviving assets – the historic urban layout, the medieval market square with its characteristic built environment, and other elements that shape local identity. This study aims to identify the evaluation criteria for the preserved historic fabric and the significance of heritage protection that guarantee the success of revitalisation. The research employs in situ investigations, comparative analysis, and an evaluation of completed revitalisation projects in selected towns and cities within the Świętokrzyskie Voivodeship, including Kielce, Sandomierz, Chęciny, Bodzentyn and Wiślica.

Keywords: Świętokrzyskie, revitalisation, market square, historic monument, conservation, protection

Streszczenie

Rewitalizacja obejmuje działania ukierunkowane na rozwiązywanie problemów społecznych, gospodarczych i przestrzennych – zwłaszcza w mniejszych miastach – a jednocześnie odgrywa istotną rolę w ochronie dziedzictwa kulturowego. Autorka omawia to zagadnienie na przykładzie wybranych miast regionu świętokrzyskiego o średniowiecznym rodowodzie, w których władze lokalne podejmują inicjatywy rewitalizacyjne, by przywrócić im dawną świetność i poprawić ich funkcjonalność. W procesie tym często wykorzystuje się najcenniejsze zachowane zasoby: historyczny układ urbanistyczny, średniowieczny rynek z charakterystyczną zabudową oraz inne elementy kształtujące lokalną tożsamość. Celem niniejszego opracowania jest określenie kryteriów oceny zachowanej tkanki historycznej oraz znaczenia ochrony dziedzictwa dla powodzenia rewitalizacji. Badanie opiera się na wizjach lokalnych, analizie porównawczej oraz ocenie zrealizowanych projektów rewitalizacyjnych w wybranych miastach województwa świętokrzyskiego, w tym w Kielcach, Sandomierzu, Chęcinach, Bodzentynie i Wiślicy.

Słowa kluczowe: Świętokrzyskie, rewitalizacja, rynek, zabytek, konserwacja, ochrona

1. INTRODUCTION

The Świętokrzyskie region, located in south-central Poland, features numerous small cities and towns with municipal rights. Towns in the Świętokrzyskie Voivodeship that have retained municipal rights since their medieval incorporation include Kielce (1364), Sandomierz (1282) and Chęciny (c. 1325). Wiślica obtained charter status even earlier, in 1326, but lost it in 1870, eventually regaining it in 2018, when it became the smallest town in Poland with a population of 503 residents. Bodzentyn held municipal rights from 1355 to 1870, subsequently reclaiming them in 1994. Medieval incorporation under Magdeburg Law was permanently embedded in the fabric of these towns, and manifests as a regularly-shaped market square and a geometric street grid that continues to form their core to this day. By the tail end of the 20th century, and particularly from the first years of the 21st century, local heritage assets emerged as an antidote to the local problems plaguing these small towns. Revitalisation programmes began improving the difficult situation of small Polish towns, leveraging heritage to elevate the quality of both the urban space and residents' lives. Consequently, during the first decade of the 21st century, every other municipality in the Świętokrzyskie region secured EU funding for revitalisation-related projects. As of today, virtually every town in the Świętokrzyskie Voivodeship strives to develop a Local Municipal Revitalisation Programme for the town and commune, and then to subsequently implement these projects to achieve the intended goal – boosting both investment and tourism appeal. This has been, and remains, the case for cities and towns such as Sandomierz, Kielce, Chęciny, Bodzentyn and Wiślica.

2. RESEARCH AIM AND SCOPE

This paper aims to outline the criteria for assessing the preserved historic space and the significance of conservation and protection, which guarantee the successful execution of revitalisation projects. The scope of the study covers towns and cities with medieval roots whose urban space retains the imprint of Magdeburg Law incorporation, namely a market square and a geometric street grid alongside its built environment. To achieve this objective, *in situ* studies were conducted in selected cities and towns across the Świętokrzyskie Voivodeship – Kielce, Sandomierz, Chęciny, Bodzentyn and Wiślica – where market square revitalisation projects have taken place. The evaluation of these projects relies on a comparative method, drawing conclusions that establish the

significance of cultural heritage as a key criterion in such undertakings.

The cities and towns were selected for study based on several criteria: first, the period of origin – medieval incorporation and the status of municipal rights; second, the state of preservation and function of the market square, its buildings, and other structures defining the site's identity; the decisive criterion, however, was whether revitalisation works had been carried out within the market square area.

2.1. The medieval market square and revitalisation

Revitalising a historic public space – a market square with medieval roots – presents unique challenges, varying according to the current state of preservation of the architectural and urban layout and its function prior to revitalisation. The state of preservation and function constitute the two primary criteria for evaluating the urban layout and historic fabric before drafting a revitalisation programme with public participation, and subsequently formulating the resulting action plans. Urban layouts of historical value are typically entered into the register of historic monuments¹, which inherently aims to safeguard the most valuable elements of the original town planning and the spatial composition of the complex, which comprises the built environment with its subsequent alterations and extensions. As a result, alongside the general layout, conservation protection extends to the division of plots, the size and volume of buildings, the spatial relationships between elements of the development, the appearance of façades², and their architectural decoration. This imposes conservation constraints that both heritage protection authorities and municipal governments must address within their planning frameworks. The success of revitalisation projects stems from reconciling the interests of both authorities; their shared goal, however, is – or at least ought to be –

¹ Kielce – urban and landscape layout of the city of Kielce, reg. no.: A.321; Bodzentyn – spatial layout (layout and internal/external landscape), reg. no.: A.214; Chęciny – urban and landscape layout of a historic town with the layout of squares, streets and buildings, reg. no.: A.228 of 9.01.1947 and 264 of 15.02.1967; Sandomierz – Urban-architectural and landscape complex with an extended conservation zone of a historic town, encompassing the entirety of its existing historical built environment, as well as the areas surrounding and linked to the town, reg. no.: A.719; Wiślica – town-settlement as a historic town, reg. no.: A.84 (register entry no. 113 of 22.12.1986).

² Judgement of the Voivodeship Administrative Court in Warsaw of 23 May 2014, case ref. VII SA/Wa 188/14. Cf.: Entry in the register of historic monuments, 29 December 2021 [1].

the preservation of tangible and intangible heritage for contemporary users and future generations.

Considering these criteria, the resulting actions, and the degree of necessary intervention, the author picked a number of examples illustrating approaches to the revitalisation of market squares with varying degrees of preservation regarding their historic urban layout, architectural fabric and existing function, yet characterised by comparable sizes (Tab. 1).

Table 1. Comparative table of market square sizes (author's own work, 2026)

No.	Town/City	Area [hectares]	Plots
1.	Sandomierz	1.03 ha	district 0003, no. 1135/1
2.	Kielce	0.56 ha	district 0016, no. 216/1
3.	Chęciny	0.65 ha	district 0002, no. 2203
4.	Bodzentyn	0.63 ha	district 0001, no. 2987
5.	Wiślica	0.66 ha	district 0001, no. 431

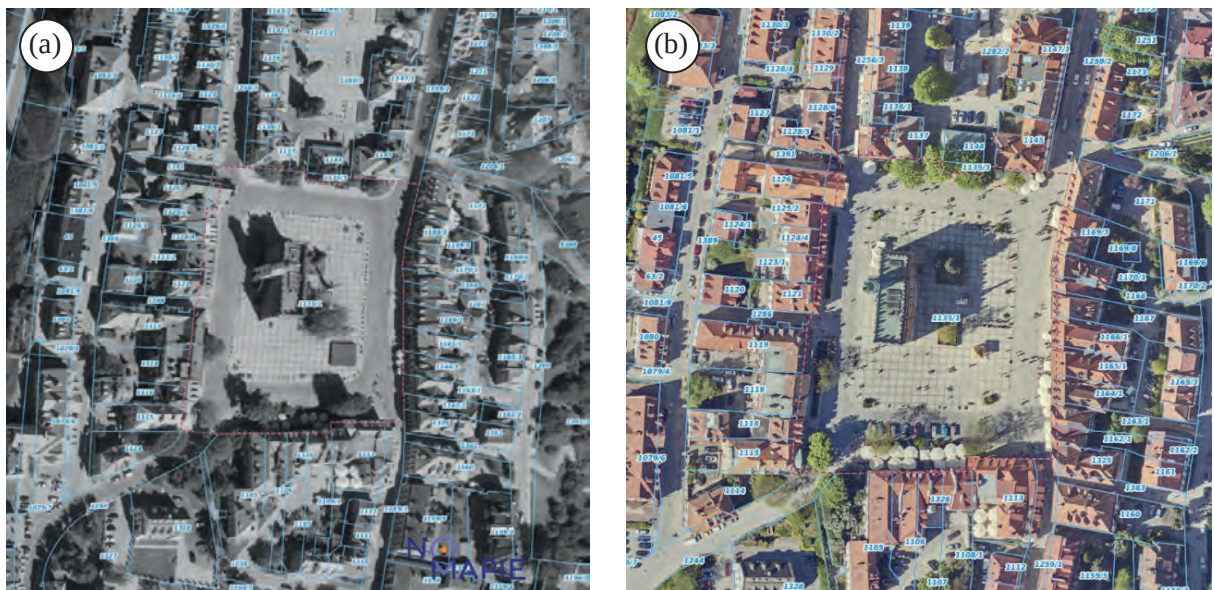


Fig. 1. Sandomierz – Market Square: (a) Aerial photograph taken in 2003 [Archival aerial photograph report, retrieved: 06.05.2026]; (b) Aerial photograph taken on 27.04.2025 [Archival aerial photograph report, retrieved: 06.05.2026]

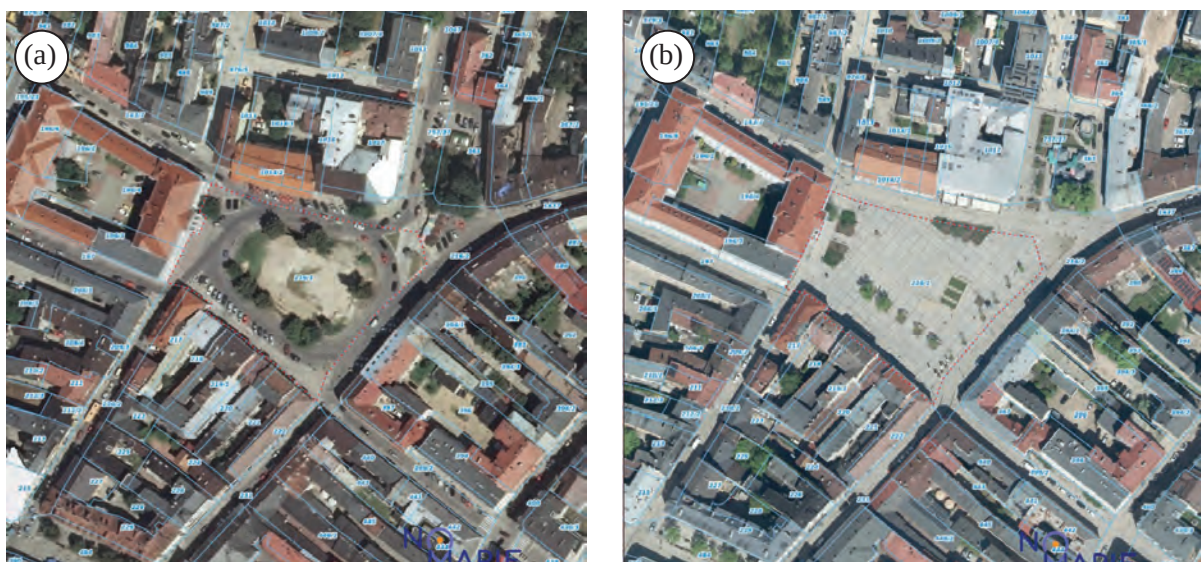


Fig. 2. Kielce – Market Square: (a) Condition before 2010. Aerial photograph taken in 2009 [Archival aerial photograph report]; (b) Kielce – Market Square. Current condition since 2024. Aerial photograph taken on 27.04.2025 [Archival aerial photograph report, retrieved: 06.05.2026]



Fig. 3. Chęciny – Market Square: (a) Condition before 2013. Aerial photograph taken in 2009 [Archival aerial photograph report, retrieved: 07.05.2026]; (b) Current condition since 2014. Aerial photograph taken in April 2025 [Archival aerial photograph report, retrieved: 07.05.2026]



Fig. 4. Bodzentyn – Market Square: (a) Bodzentyn. View of the Upper Square in Bodzentyn (1961-1963) [2]; (b) The intended effect of applying conservation guidelines involving greenery [3]



Fig. 5. Wiślica – Market Square: (a) Condition in 1967 [Source: [4]]; (b) Current condition. Aerial photograph taken on 27.05.2024 [Archival aerial photograph report, retrieved: 07.05.2026]

The market square in Sandomierz was chosen as the best-preserved urban development concept of its kind in its original setting, which did not undergo any major changes over the centuries (Fig. 1). The remaining examples comprise market squares which have lost their commercial function in favour of transport infrastructure and green spaces established in their central sections, which was the case in Kielce, Chęciny and Bodzentyn, and which subsequently regained their prestigious status as public spaces through revitalisation (Fig. 2, 3, 4). Wiślica, by contrast, serves as an example of a situation where the market square retained the form into which it had evolved—an urban green area (Fig. 5).

2.2. Revitalisation of preserved market squares

Sandomierz is a city on the Vistula River, located 94 kilometres south-east of Kielce, situated in south-central Poland in the Świętokrzyskie Voivodeship and Sandomierz District. Initially, in the 10th century, it existed as a settlement, then turned into a stronghold with suburbs in the 11th century. The fortifications fell in the mid-13th century. In the second half of the 13th century, the centre of Sandomierz was relocated from Old Town Hill to Town Hill. This *translatio civitatis* was formally sealed by the incorporation charter of 1286, and the new location was anchored by the market square, which remains the heart of the town and its Old Town district to this day [5, p. 121] (Fig. 1). The rectangular square was laid out on the highest elevation within historic Sandomierz, featuring a characteristic geometric network of streets radiating from its corners and quarters divided into plots where townhouses were erected to form continuous frontages (Fig. 2). The two-storey townhouses feature relatively high ridged gable roofs with dormers. Back in the Middle Ages, a town hall was built in the northern part of the market square, and subsequently remodelled and extended during the Renaissance. This well-preserved building remains functional today, housing a branch of the District Museum and the Register Office, while its cellars host the *Lapidarium* club.

The historic centre of Sandomierz avoided major wartime destruction; however, considerable time has passed since the war, and much could have changed, yet this did not happen. In reality, Sandomierz can be seen as an open-air historical and architectural museum. Visitors can experience all the subsequent eras thanks to more than 120 preserved historic buildings representing all architectural styles. This was fostered by a policy of care for the historic space implemented from the

very outset, as evidenced by early archive records [6], alongside superb cooperation between the authorities and the conservation officer from the beginning of his tenure. From the start, even before the war, the conservation officer Andrzej Oleś campaigned for the proper protection and maintenance of the town's historic character [7]. This remains the case today, thanks to the Sandomierz branch office of the Voivodeship Heritage Conservator in Kielce. As a result, the entire urban layout of historic Sandomierz is perfectly preserved to this day. The value of the town's historical heritage was further recognised and highlighted in 2021, when Sandomierz – the historic architectural and landscape complex – was designated a Historic Monument.

Safeguarding historical values and maintaining this state of preservation requires continuous care, protection and conservation, alongside revitalisation – which in Sandomierz's case focuses primarily on aesthetic matters, repairing the surface of the square, pavements and roadways, and occasionally spatial projects concerning new elements. The market square in Sandomierz is a *complete space* – compact, well-maintained and undisturbed. The introduced and variable elements comprise street furniture designed to blend into the historic space. These include lanterns, which ought to be uniform, litter bins and benches, as well as cohesive decorative elements on façades that go hand in hand with the historic character of the buildings. This is particularly true for advertising, which has been replaced by signposts for the shops and other businesses operating in the townhouses.

Between 2001 and 2012, road works and utility overhauls were carried out across the entire town of Sandomierz, and the infrastructure within the Old Town boundaries was completely rebuilt. In the subsequent years (2014–2020), the town carried out tasks within the framework of the EU project *Revitalisation of Sandomierz – a City of Cultural Heritage and Development* [8]. The primary objective of the project, for which the town secured EU funding from the Regional Operational Programme, was the socio-economic revival and the physical and spatial renewal of Sandomierz's revitalisation area; this also included the renovation and adaptive reuse of degraded buildings to restore or assign them new social, economic, educational and cultural functions. Thanks to the initiatives driven primarily by the municipality, all the townhouses are regaining their former glory, and the Old Town is growing more beautiful. Furthermore, the wooden benches in the Market Square were replaced with new ones made of steel-framed Pilkington multi-

layer laminated glass. Additionally, glass display panels were installed. This so-called *glass walk* is designed to help visitors explore Sandomierz and learn the history of its monuments (Figs. 6, 7). A plaque installed in the corner of the Sandomierz market square displays the town hall alongside a monument to the Tsar that stood there until 1928³. To reproduce the 1870s engraving onto the glass, ceramic printing technology was employed, and the printed elements were placed between two laminated panes of glass. The primary aim of these measures is to improve the quality of life for the local community and, among other things, to enhance the town's tourism potential. The revitalisation has enhanced both the usability and aesthetics of the space without disrupting the preserved fabric; the added elements integrate seamlessly, providing added value to the contemporary residents.



Fig. 6. Sandomierz, eastern frontage of the market square (M. Doroz-Turek, 2021)



Fig. 7. Sandomierz, Town Hall – view from the south-west corner of the market square (M. Doroz-Turek, 2021)

³ A monument of gratitude for the enfranchisement of peasants, erected in 1865 at a prominent point in Sandomierz.

2.2.1. Revitalisation of lost market squares in Kielce, Chęciny and Bodzentyn

In Poland, most market squares of medieval origin lost their significance during the second half of the 20th century. The commercial function of the market squares, which hosted fairs where peasants and artisans sold their produce and wares, persisted for quite a long time – until the interwar period, and in many cases even until the mid-20th century [9, pp. 78-83] [10]. During the interwar period, the authorities began introducing trees into the empty squares along the frontages. Even earlier, in the 19th century, tram lines and associated stops were introduced to market squares in cities such as Warsaw (1866), Wrocław (1877), Poznań (1880) and Kraków (1882); in 1952, the last trams ran through the market squares of Kraków and Poznań, with the decision to dismantle the tram lines justified by the need to protect the historic Old Town, while in Wrocław they continued to run until the late 1970s⁴. Motor vehicle traffic also emerged after World War II. This state of affairs continued until at least the 2nd half of the 20th century. It was only at the end of the 20th century, and especially at the beginning of the 21st century, that the need to create public spaces arose, especially in the Old Towns and city centres. The market square, standing as a testament to the past, proved to be the perfect example; through revitalisation, local authorities turn them into prestigious and universally accessible spaces, designed with people and society in mind.

Kielce, the capital of the Świętokrzyskie region, exemplifies a Polish city with medieval roots. The history of the oldest trading settlement can be traced back to the turn of the 10th and 11th centuries. The incorporation of Kielce may have occurred even before 1227, when Bishop Iwo Odrowąż obtained the right from Prince Leszek the White to settle German immigrants through mediation [11, p. 208]. The culmination of Kielce's urbanisation, despite its low population and its commercial and agricultural character, came with its incorporation under Magdeburg Law in 1364 [12, pp. 53-54] [13, p. 23]. At that time, a marketplace – a market square in the shape of an irregular rectangle – was laid out adjacent to the trading settlement; its form was dictated by an existing road (today's Bodzentynska Street, which then turns into Duża Street), which was left unaltered. As

⁴ On 27 June 1952, the last tram rolled into Kraków's Market Square. In Wrocław, trams continued to run to the market square until the late 1970s.

a departure from the regular layout of perpendicularly radiating streets, the street in the north-eastern corner runs diagonally, akin to Grodzka Street in Kraków.

A brick town hall was erected in the market square in the first half of the 16th century, testifying to the status of Kielce as a city. The building burned down at the beginning of the 19th century during a city fire [14] [15, pp. 27, 52, note 3], after which it was demolished and never rebuilt [16, p. 315] [17, p. 36]. The underground remains of this freestanding historic town hall were first encountered in 1943, during the construction of a firewater reservoir by the Germans (Fig. 8) [18, p. 130] [15, p. 27] [19, pp. 198-199].



Fig. 8. Kielce. The Market Square with fountain in the middle, before 2008 [36]

In addition to the town hall, by the end of the 18th century continuous frontages enclosed the market square, including six brick townhouses and ten partially brick ones. The remaining buildings were wooden, but following their destruction in fires, they were replaced by brick structures [18, p. 30]. All houses within the blocks facing the square were fronted by arcades [18, pp. 130-133], or simply featured brick façades, which Adamczyk marked on his plan [15, p. 30, Fig. 19]. This distinctive character of the built environment surrounding the square is evidenced by two arcaded townhouses – at Rynek 18 (the townhouse known as the Sołtyk House) and Rynek 4 (currently housing the Museum of Dialogue and Cultures). Between 1945 and 1948, a vision for the post-war redevelopment of the inner city and the expansion of Kielce was formulated by the Warsaw-based architect Bohdan Pniewski [20, p. 66], for whom Kielce became a second centre of professional activity outside Warsaw during the occupation [13, pp. 181-195] [21]. Accounts indicate that, *owing to his connections with prominent clergy, he designed the inner city of Kielce with medieval characteristics – priests' residences on one side, and guild*

artisans (goldsmiths, makers of devotional items and clerical vestments) on the other [22]. While references in written records confirm that the architect worked on this plan alongside a team in Kielce, which included Jerzy Król, no iconographic sources are known to exist. The contract to draft an outline development plan for the Kielce urban complex within the context of the wider Kielce region was signed with Bohdan Pniewski on 24 April 1945. This is confirmed by a document certifying the acceptance of works executed by the architect [21] and by earlier sources [23, 24].

Józef Kłodawski also conceived visions for the future of Kielce. In a study penned during the occupation titled *The Future Kielce* [26], the author formulated a vision for the city's future, outlining its regional role and developmental prospects against a backdrop of cultural and economic life, alongside the city's physical appearance [27]. He sketched out a multifaceted portrait of the city, focusing specifically on the *Kielce Acropolis* – an architectural gem – and its premier civic space, namely the Old Market Square. Kłodawski notes that various architectural proposals for the market square buildings existed at the time, including arcaded houses and designs focused on the Renaissance style. Like Pniewski's aforementioned project, these plans were never executed.

In the 1960s, the firewater reservoir was converted into a fountain, which remained there until 2008 (Fig. 8) [20, pp. 198-199]. During this period, the square functioned as a traffic junction – a roundabout with the aforementioned fountain at its centre, a few trees, a lawn and benches – bearing no resemblance to a historic market square, save for the surrounding townhouses enclosing the space.

The modern revitalisation of Kielce theoretically commenced in the 1990s, when a vision for 21st-century city first emerged. Jacek Nowakowski worked on the development plans for the city centre⁵. Their main aim was to free the city centre from car traffic. The plan approved by the councillors envisaged that: *The roundabout and fountain will disappear from Kielce Market Square, leaving only a few trees – the entire square is to become a level and open space in order to uncover and enforce its historic character*⁶. The architects' plan to get rid of traffic from the centre

⁵ Jacek Nowakowski was born in 1953 in Kielce. He studied architecture in Kraków. After completing his degree, he worked as an architect and painted [28].

⁶ Krzysztof Krogulec wrote about the planned changes in 1994 in a Kielce daily newspaper [29].

of Kielce was intended to facilitate pedestrian traffic and reflected a desire to reveal its history. Design competitions for the development of Sienkiewicza Street and the Market Square, then known as Partyzantów Square, were held in 1993. However, works did not commence until the new century under the project *Revitalisation of the Historic Inner City of Kielce – Redevelopment of the Market Square and Surrounding Streets*⁷. The project's main goal was to boost the socio-economic and spatial activity of Kielce. The revitalisation carried out in 2010–2011 enhanced the aesthetics of the area and improved the residents' quality of life. As initially intended, efforts focused on restoring the original form and function of the square by restricting car traffic, transforming the site into a venue for meetings and strolls for residents and visitors alike. Whether this succeeded could be evaluated more than two decades later. In the residents' view, Kielce undoubtedly reclaimed its Market Square, the heart of the city which had been completely lost [30]. During the revitalisation, the surviving remnants of the town hall walls were uncovered once again and subsequently left underground; however, their outline was marked in the market square paving and there are sections of the wall raised above the surface, which bring the image of the ruins to mind. As a result, the lost architectural heritage was commemorated within the public space and its memory was restored through a trace in the new paving [19]. In modern times, this historic area and its historic buildings have been used by the authorities to develop and promote the city – the capital of the Świętokrzyskie region. The so-called *Urban Salon* was also arranged in the market square – a unique initiative encompassing 180 square metres of the area. The idea of the initiators from Kielce Institute of Design was to create a space resembling a living room, where one can relax or receive guests (Fig. 9) [31]. Consequently, planters with greenery and furniture, such as seats and deckchairs, were installed in the market square. The residents of Kielce were actively involved in this public project, and the concept was consulted with them. The project received high acclaim, and the architects of the Kielce Institute

of Design won an award for the Urban Salon in the prestigious competition hosted by the Institute of Industrial Design – 2013 Good Design.



Fig. 9. Kielce, The Market Square – Urban Salon
(M. Doroz-Turek, 2015)

Thanks to thorough revitalisation, the Kielce market square has regained its original significance as a public square, becoming a space used by residents as a venue for meetings and local events, as well as a point of interest highly appreciated by visitors (Fig. 10).



Fig. 10. Kielce. The Market Square before 2023
(M. Doroz-Turek, 2021)

Despite the significant success of the project and the revival of the square, there were voices of those dissatisfied with its outcomes. The project was chiefly criticised – as in the case of many other towns where similar revitalisation projects had been carried out [32] – for covering the city centre in concrete and the removal of greenery.

A decade later, the local authorities initiated projects aimed at adding greenery and unsealing parts of the

⁷ It encompasses the reconstruction and expansion of the Market Square and St Tekla's Square, as well as the surrounding Mała and Duża streets, the redevelopment and construction of technical infrastructure and street furniture elements, alongside the removal of the existing underground toilet. All structural elements of the roads and pavements will be replaced, along with the reconstruction of storm water drainage, street lighting and conflicting technical infrastructure.

market square surface. The *Green Revitalisation of the Historic Inner City of Kielce* project [33, 34] represents works for which the city of Kielce secured funding from the Strategic Investment Programme. The works commenced in 2023 and will conclude in the spring of 2024. The market square now features trees planted directly in the soil (Fig. 11).



Fig. 11. Kielce. The Market Square after 2024
(M. Doroz-Turek, 2026)

As part of the recent revitalisation of the market square in Kielce, the square was partially unpaved to plant trees and low-growing greenery. Spurred by the calls and protests of Kielce residents, the original design – which also envisaged removing pavement and new plants in the central section of the square – was scaled back; some feared that the market square could have lost its function of a public space, turning into yet another park. Preserving a venue capable of hosting various events organised by the city, including a space for building a large stage, was seen as vital [35]. The new trees were planted directly into the soil and are watered with an underground irrigation system. New street furniture elements were also introduced, including benches, bins, information boards and bicycle racks [34]; the aforementioned *Urban Salon* was relocated to Literatów Square.

Chęciny is a small town located to the west of Kielce. The history of Chęciny dates back to the mid-12th century, and the settlement was originally located elsewhere, at a site now known as the village of Starochęciny. Chęciny gained significance with the construction of a fortified medieval Royal Castle on the rocky ridge of Castle Hill, (360 metres above sea level). A new settlement was established at the foot of the hill at the turn of the 14th century which, thanks

to the prominence it achieved under King Władysław I the Elbow-High, was incorporated under Magdeburg Law after 1306 (c. 1325)⁸; as of then, the ducal castle in Chęciny was already there. Concurrently with these rights, a regular market square and an orthogonal street grid were laid out. The entire urban layout was oriented visually towards the fortress towering over the surrounding area. The town hall was erected in the market square, which exists to this day as 2 Czerwca Square. The building survived until the mid-17th century. Today, the market square is surrounded by townhouses, some displaying architectural features dating back as far as the 15th century. Unfortunately, many of the buildings no longer exist, such as the Kozubowicz Townhouse, of which only the cellars survive beneath the current building, featuring the oldest stone portal dating back to the 15th century.

The main tourist attraction in Chęciny is the castle, preserved as a ruin which retains a clear form reminiscent of the magnificent original structure. The numerous tourists visiting the area focus on the castle. Until recently, very poor technical infrastructure discouraged exploration of Chęciny's centre, while the lack of tourist services deterred visitors from extending their stay and fully utilising the space. In order to remedy this situation, as well as attract and retain both residents and visitors in the centre, in 2013–2014 a comprehensive revitalisation of Chęciny's market squares along with adjacent streets was carried out, aimed at rebuilding and promoting the unique historical and cultural features of the area [37].

The design guidelines for the revitalisation of the Market Square – 2 Czerwca Square, were preceded by historical and urban analyses conducted by Dariusz Piotrowicz [38, pp. 121-142]. The completed analysis did not, however, offer a ready-made solution for this vital urban area and public space, but *revealed its hidden historical and spatial values, which serve as a foundation for further revitalisation efforts*. The main premise of the revitalisation was to clean up and open up the public space, as well as to highlight the urban compositional elements and landscape vistas of the architectural landmarks, including the castle. Elements of the former layout were also recreated, including arcades, a well and market stalls, which are set up occasionally (Fig. 12). Motor traffic on the square was restricted, while street

⁸ The incorporation charter has not survived. The incorporation of the town can be traced back to the reign of King Władysław I the Elbow-High, 1306–1325.

furniture and greenery were introduced along the eastern and western frontages. Alongside preserving and bringing out the square's values, the project focused on improving the quality of space in this small town, impacting its economic and commercial development: namely tourist services, small-scale catering, accommodation, etc. [39, p. 15].



Fig. 12. Chęciny. The Market Square following its revitalisation [43]

In 2013, despite the immense interest in the ruins of Chęciny Castle, this site was also subjected to revitalisation and adaptive reuse for tourism purposes. The project works, which focused on meeting contemporary technical conditions and standards, were carried out with respect for the historic heritage of the site. Excavation works revealed new and previously unknown architectural artefacts of the castle, which dates back to the turn of the 13th and 14th centuries. After securing the discoveries, the revitalisation of the castle ruins commenced in the spring of 2013, based on a design concept developed back in 2005. During this time, a comprehensive renovation and landscaping works were carried out with the aim of making the monument more attractive to tourists. Following the completion of the revitalisation, interest in the castle increased by 60% compared to the period prior to these interventions.

Bodzentyn is yet another small town with municipal rights in the Świętokrzyskie region boasting a rich history that stretches back to the Middle Ages. The town is surrounded by a beautiful landscape – it borders the Świętokrzyskie National Park and the Łysogóry range in the the south-west and is located roughly 30 kilometres north-east of Kielce. Many hiking trails intersect in Bodzentyn, due to the rich landscape values and the saturation of preserved

cultural heritage in the area⁹. In this town, visitors are drawn primarily to the preserved ruins of the former Krakow Bishops' Palace¹⁰, the 15th-century Gothic church and the market square.

Bodzentyn was founded and incorporated around 1355 by Bodzęta, the Bishop of Kraków [40, p. 25]. In the second half of the 14th century, a subsequent bishop erected a medieval castle. The site for the episcopal residence was selected as the layout of the town was decided at the time of its incorporation. Bodzentyn held great significance during the medieval and Renaissance periods; during this time, the residence was rebuilt following a fire in 1413 and subsequently expanded by successive bishops over the following centuries, with the first expansion of the castle carried out by Bishop Zbigniew Oleśnicki (1423-1455), and at the end of the 15th century by Bishop Fryderyk Jagiellończyk (1488-1503). Bishop Franciszek Krasiński (1552-1577) was the main originator of the overhaul of the Gothic castle and the erection of a magnificent bishop's residence in Renaissance style. The works were completed by Bishop Piotr Myszkowski (1577-1591). Significant changes to the castle took place from the beginning of the 17th century on the initiative of Bishop Piotr Tylicki (1608-1616). The building was eventually rebuilt on a horseshoe plan and consisted of the southern and northern wings, which were connected to the east by the Grand House. Thanks to the funding provided by Bishop Piotr Gembicki (1642-1657), the entire structure was linked by a single communication system with stairs, an arcade loggia and an overlooking gallery [41].

In the early 17th century, the palace in Bodzentyn experienced its heyday as a summer residence of the bishops of Kraków, bustling with cultural life – and the town reaped the benefits. It soon lost its importance in favour of the new palace built in Kielce between 1637 and 1642¹¹ (1644¹²) at the initiative of Jakub Zadzik, the Bishop of Kraków – a residence ranked at the time among the most beautiful buildings in Poland [13, p. 218]. The brilliance of the Kielce palace eclipsed not only the residence in Bodzentyn, but also the castles in Iłża, Lipowiec and Siewierz.

⁹ The Wooden Architecture Trail, the Defensive Architecture Trail, the Archeo-Geological Trail, the Literary Trail.

¹⁰ Register of Monuments no.: ruins of the castle with courtyard, reg. no: A.217/1-4 of 15.02.1967 and 17.02.1957.

¹¹ Works commenced in the years 1636–1637. Cf.: [42, p. 155, note 14].

¹² The year the interior works were completed [43].

From the mid-17th century, the town of Bodzentyn unfortunately also began to decline. The decline worsened following the seizure and nationalisation of episcopal estates in 1789. In the hands of the Austrian occupying authorities, the palace served as a granary and a military hospital, which led to its destruction. After 1815, it became the property of the government of the Congress Kingdom of Poland and was subsequently abandoned. As a result, it began to fall into disrepair. During the 1830s, the defensive walls and the Opatowska Gate were demolished, and the market square was transformed into a green space surrounded by roads (Fig. 4a). Shortly thereafter, in 1870, Bodzentyn lost its municipal rights, eventually regaining them in 1994. Upon recovering its town charter, the municipality sought to restore its former status and significance within the Świętokrzyskie region, as the quality of public space had also deteriorated. The authorities saw an opportunity to achieve this goal by undertaking urban revitalisation initiatives that leveraged the preserved cultural assets. Within the framework of the Local Revitalisation Programme for Bodzentyn, a public space development concept was drafted between 2012 and 2013. Based on its premises, a redevelopment scheme for the Main Market Square and the surrounding streets was drafted. In this case, the functional revitalisation of the market square consisted of restoring the original function and creating a town centre that was friendly to residents and visitors alike [39, p. 15] [35, p. 7]. During the revitalisation works in Bodzentyn market square, the foundation walls of the 17th-century town hall, which had been demolished in 1832, were unearthed. Following this discovery, changes had to be introduced to the design of the paving, which now delineates the outline of this historic structure (Fig. 4b, 13).



Fig. 13. Bodzentyn. The Market Square following its revitalisation. A bird's eye view [44]

The project enhanced the aesthetics of the public space by organising the square, replacing the paving and introducing street furniture, while mature trees were replaced with low-growing greenery. At the same time, plans were made to revitalise the ruins of the former episcopal palace. Despite the development of a concept for the site, no restoration or adaptive reuse works were undertaken at that time. It was not until 2024 that a controversial project was approved and implementation work commenced at the ruins of the Bodzentyn palace.

2.2.2. Revitalisation of the lost market square in Wiślica

Wiślica, a medieval gem of the Ponidzie region situated on the Nida River, was until recently the smallest town not only in the Świętokrzyskie region, but in Poland as a whole. The town lost the municipal rights it had obtained in 1326 in 1870, eventually regaining them in 2018. The fact that Wiślica was a prominent hub in historic Lesser Poland¹³, alongside Kraków and Sandomierz [45], is evidenced by numerous monuments dating back to before its incorporation. These include the remains of a fortified settlement: two rotundas, two palatia, and two Romanesque churches, along with a crypt associated with one of them that features a rich plaster floor known as the Orants' Slab (the Wiślica Slab), dating back to the third quarter of the 12th century. Wiślica was presumably incorporated under Magdeburg Law in the first half of the 14th century, and in the mid-14th century, under Casimir the Great, the town was enclosed by defensive walls. The incorporation is evidenced by the orthogonal 9-field urban layout of the centre, featuring a small market square built on an irregular square plan measuring approximately 2 x 2 cords¹⁴, enclosed by compact development comprising predominantly single-storey buildings with attics under ridged gable roofs. Originally, the buildings were mainly timber-framed; sources indicate that by the end of the 18th century, only one brick building stood in the market square, described as an inn (known as the Rosary Townhouse at Rynek 34). The town hall erected in the square was also wooden [46] [47, p. 184]. Furthermore, the houses currently surrounding the market square date back to the 19th and 20th centuries – some of them were

¹³The territory of historical Lesser Poland currently encompasses the south-eastern part of the country, roughly corresponding to today's Lesser Poland, Świętokrzyskie and Podkarpackie voivodeships.

¹⁴1 large cord = 10 rods = 75 cubits = 150 feet = 44.665 metres; a non-mathematical unit of length historically used in Poland.

erected over older vaulted cellars. In 2018, Wiślica – the collegiate church ensemble of the Nativity of the Blessed Virgin Mary with the remnants of the church of St Nicholas and the hillfort site – was designated a Historic Monument.

For the years 2007-2013, in connection with the town's millennium, a project entitled *The Millennium of Wiślica – Traces of Former Splendour* was launched in the Wiślica Municipality, encompassing the revitalisation of the archaeological pavilion and the basilica's underground vaults, alongside the redevelopment of the market square. The overall aim of the project was to improve tourist facilities and make use of historic buildings for this purpose; hence the programme included the restoration of the Market Square and its adjacent streets. Restoration work began at the end of 2012 and was completed in 2014 (Fig. 5b, 14). In connection with this project, remedial works were carried out, including the resurfacing of park pathways, the installation of new benches and lanterns, and a new bus shelter; in the middle of the park, a 5-metre circle featuring the coat of arms of Wiślica was crafted from paving blocks (Fig. 14).



Fig. 14. Wiślica. The Market Square after its revitalisation [48]

Beyond the former market square, the surfaces of the adjacent streets extending perpendicularly (Targowa, Okopowa) and Solny Square were also replaced. During the recent revitalisation, the current function of the market square was retained, and the green municipal square was refreshed. The result is a friendly, well-kept space with alleys and benches for residents and visitors alike. It was a primarily aesthetic revitalisation, mostly concerned with tidying the space and removing replaced street furniture elements. However, the designation of the former market square was not altered, which during the 20th century had assumed the character of a municipal green area; the commercial function was taken over by

Solny Square, which gained more importance than the original market square.

In each case, revitalisation works are conducted with respect for history, based on meticulously executed research and thorough analyses identifying the condition of historic monuments and other buildings, which lead to the formulation of design assumptions. The state of preservation of cultural heritage is of paramount importance, as the degree of intervention during revitalisation depends entirely upon it. In Sandomierz, the market square required only a minor aesthetic overhaul and adaptation to the needs of contemporary users. In the cases of Kielce, Chęciny and Bodzentyn, the revitalisation of market squares restored their prestigious character due to restriction of vehicular traffic, thereby creating a safe space for pedestrians alongside a venue for gatherings and hosting events. In Wiślica, the revitalisation comprised solely works aimed at refreshing the space. The designers preserved the green area given the current importance of the town. One could argue that Wiślica had lost its true market square; however, following the trend of market square revitalisations widely criticised for paving over the areas, the revitalisation in Wiślica aligns with the new green revitalisation trend.

3. CONCLUSIONS

In addition to passive protection and conservation of historic monuments, the 21st century demands significantly more from interventions carried out in historical urban spaces. An informed yet demanding society expects better living spaces. Cultural heritage has become the key factor in improving the environment, which is why it is leveraged as part of the revitalisation processes. Local revitalisation projects and schemes lead to improvements in the quality of life, particularly in small towns and cities. The revitalisation of Polish towns has also become a way of preserving cultural heritage, which is particularly important given the pressing need for its protection and sustainable use. The aforementioned examples of towns and cities in the Świętokrzyskie region demonstrate how their historical tangible heritage in the form of preserved market squares and built environments, serves this end. The types and scales of interventions carried out as part of revitalisation projects are influenced by the state of preservation of public spaces, as well as their current function. The success of an implementation depends on exploiting the potential of the historic spaces, but also on the towns'

contemporary significance. However, one has to agree that revitalisation projects are extremely important in modern times. Cultural heritage holds immense potential and constitutes a factor in local development, while spatial changes leveraging historical assets drive the economic and social advancement of small towns. It is evident that as society evolves, the town evolves

alongside it; therefore, one must be ready for changes – a phenomenon which is best exemplified by Kielce. In this city, a decade after the initial revitalisation of the market square, another project was carried out in response to global climate change, with future generations in mind.

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THE INFLUENCE OF DISPERSED REINFORCEMENT IN THE FORM OF BASALT FIBERS ON THE STIFFNESS MODULUS OF ASPHALT CONCRETE

WPŁYW ZBROJENIA ROZPROSZONEGO W POSTACI WŁÓKIEŃ BAZALTOWYCH NA MODUŁ SZTYWNOŚCI BETONU ASFALTOWEGO

Wiktorja Ściga, Przemysław Buczyński*, Grzegorz Mazurek
Kielce University of Technology, Poland

Hümevra Bolkar Tosun
Aksaray Üniversitesi, Turkey

Abstract

This article analyzes the effect of dispersed reinforcement in the form of basalt fibers on the stiffness modulus of asphalt concrete. The research program included an AC 16W mineral-asphalt mixture intended for a binder course reinforced with 30 mm long basalt fibers at 0.5% and 1.5% by weight, as well as options with adjusted asphalt content. Laboratory tests showed that the addition of basalt fibers significantly increases the stiffness of the mixture across the entire tested temperature range from 5°C to 40°C, achieving in the 1.5% variant (AC_1.5%) S_m modulus values nearly twice as high as those of the reference mineral-asphalt mixture (R). It was also noted that changing the binder content led to a significant reduction in stiffness at the analyzed temperatures, which may protect the pavement against low-temperature cracking. Despite differences in composition, all tested mixtures maintained high water resistance at 91–98%, confirming that proper dosing of basalt fibers without excess binder yields the most durable structure resistant to permanent deformation.

Keywords: asphalt concrete; basalt fibers; stiffness modulus; IT-CY method; temperature sensitivity

Streszczenie

W niniejszym artykule przeanalizowano wpływ zbrojenia rozproszonego w postaci włókien bazaltowych na moduł sztywności betonu asfaltowego. Program badań obejmował mieszankę mineralno-asfaltową typu AC 16W, przeznaczoną na warstwę wiążącą, zbrojoną włóknami bazaltowymi o długości 30 mm w ilości 0,5% i 1,5% masy, a także warianty z zmodyfikowaną zawartością asfaltu. Badania laboratoryjne wykazały, że dodatek włókien bazaltowych znacząco zwiększa sztywność mieszanki w całym badanym zakresie temperatur (od 5°C do 40°C); w przypadku wariantu z 1,5% dodatkiem włókien (AC_1.5%) uzyskano wartości modułu sztywności (S_m) niemal dwukrotnie wyższe niż dla referencyjnej mieszanki mineralno-asfaltowej (R). Odnotowano również, że zmiana zawartości lepiszcza prowadziła do istotnego obniżenia sztywności w analizowanych temperaturach, co może chronić nawierzchnię przed spękaniami niskotemperaturowymi. Mimo różnic w składzie, wszystkie badane mieszanki zachowały wysoką odporność na działanie wody (na poziomie 91–98%), co potwierdza, że właściwe dozowanie włókien bazaltowych – bez nadmiaru lepiszcza – pozwala uzyskać najbardziej trwałą strukturę, odporną na odkształcenia trwałe.

Słowa kluczowe: beton asfaltowy; włókna bazaltowe; moduł sztywności; metoda IT-CY; wrażliwość temperaturowa

*Kielce University of Technology, Poland, e-mail: p.buczynski@tu.kielce.pl

1. INTRODUCTION

The history of basalt fibers dates back to the 1960s, when the Soviet Union began developing this material as part of its space program, where its exceptional durability and resistance to extreme conditions were recognized. Today, these fibers are valued by road engineers for their ability to reduce thermal cracking and improve the stability of mineral-asphalt mixtures [1]. To improve the durability and performance of pavements, engineers and scientists have been using various methods to modify mineral-asphalt mixtures for years. One of the most effective solutions is the use of dispersed reinforcement in the form of fibers [2]. Among various reinforcement materials, basalt fibers are gaining increasing recognition as a natural, eco-friendly, and non-toxic alternative to synthetic and glass fibers [3]. Studies show that the introduction of basalt fibers into basalt fiber asphalt concrete (BFAC) alters the viscoelastic properties of the mineral-asphalt mixture, which directly translates into an increase in its dynamic modulus and stiffness [3]. A review article [4] presented results regarding the use of recycled fibers (PET), which were dosed at 0%, 2%, 4%, 6%, 8%, and 10% relative to the asphalt content. The test results showed that the optimal fiber content is in the range of 4–6%, or specifically 6% by weight relative to the asphalt. In his study [5], researcher Mahrez evaluated the fatigue properties and deformation of mixtures reinforced with glass fibers. Glass fibers were used to improve the fatigue resistance and deformation (rutting) resistance of mineral-asphalt mixtures. Artur Kowalczyk and his co-authors, in a scientific article [6], used fibers recycled from glass and carbon geogrids in amounts of 0.2%, 0.6%, and 1.0% by weight to investigate their effect on crack propagation resistance and the physical and mechanical properties of asphalt concrete. Cellulose fibers are mainly used in SMA (stone matrix asphalt) and OGFC (open-graded friction-course) mixtures to stabilize the binder and prevent it from washing out of the aggregate during transport and construction [7]. Researcher Tapkin investigated the effect of these fibers on the properties of asphalt and their behavior in a creep test [4], [8]. Polypropylene fibers are widely used as a reinforcing agent to strengthen asphalt concrete. In the article, fibers increase the strength, ductility, and durability of the mixture. The presented literature review indicates the validity of seeking answers regarding the influence of dispersed reinforcement in mineral-asphalt mixtures in the form of fibers. The literature review did not reveal any information on the effect of basalt fibers

on the stiffness modulus of asphalt concrete. The topic appears to be of scientific interest, as demonstrated in the article regarding the assessment of the effect of dispersed reinforcement in the form of basalt fibers on the stiffness modulus of asphalt concrete.

2. MATERIALS AND METHODS

2.1. Basalt fibers

Basalt fibers were used to evaluate the effect of dispersed reinforcement in the form of basalt fibers on the stiffness modulus of asphalt concrete. The production process for basalt fibers involves melting the basalt raw material at a temperature of approximately 1500°C, then transforming it by drawing it through small-diameter holes, which results in the formation of thin fibers that are subsequently cut into pieces of the appropriate length [9]. Basalt fibers have good resistance to acids and alkalis, low thermal conductivity, and weather resistance, and are characterized by hydrophobic properties [10]. Fibers 30 mm in length were used in the study. According to the manufacturer's information, the properties of the fibers used in the study change at a temperature of 160°C. The basalt fibers were properly conditioned before being added to the mineral-asphalt mixture. The fibers were added to the mineral-asphalt mixtures to assess their impact on the mechanical properties of AC 16W in the context of the effect of dispersed reinforcement in the form of basalt fibers on the stiffness modulus of asphalt concrete.

Figure 1 shows an example photograph of the basalt fibers under analysis.



Fig. 1. Basalt fibers 30 mm in length [W. Ściga]

2.2. Design of the mineral-asphalt mixture

Before proceeding with the design of the mineral-asphalt mixtures, a qualitative analysis was conducted on all the components used, including mineral aggregates, asphalt granules, the binder, and the basalt-based synthetic fiber additive. The limit curve method was used to design the mineral-asphalt

mixture, which allowed for achieving a gradation meeting the requirements [11] for mixtures intended for the binder course. The gradation curves for the AC 16W KR 3-4 mixture are shown in Figure 2.

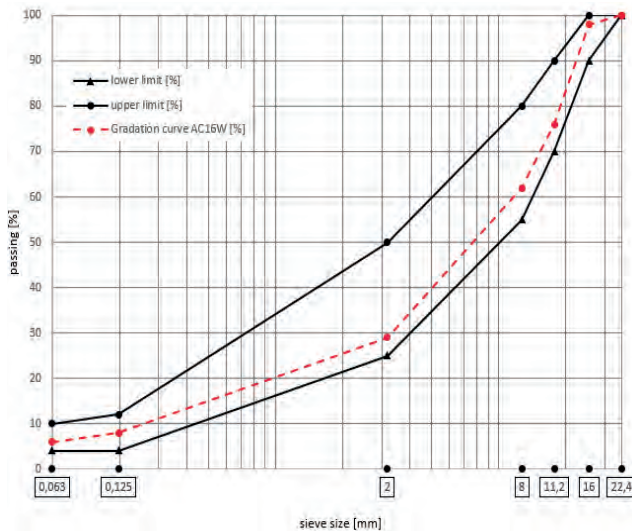


Fig. 2. Gradation curve of the AC 16W KR 3-4 mineral mixture

Table 1 shows the sieve sizes and particle size distribution of the mineral mixture under test.

Table 1. Particle size distribution of the mineral mixture

Screen hole size	Passing % (m/m)	Grain size cut-off points	
		Lower	Top
31.5 mm	100	–	–
22.4 mm	100	100	100
16.0 mm	98	90	100
11.2 mm	76	70	90
8.0 mm	62	55	80
5.6 mm	52	–	–
4.0 mm	44	–	–
2.0 mm	29	25	50
0.125 mm	8	4	12
0.063 mm	6	4	10

The composition of the mineral-asphalt mixtures is presented in Table 2.

Table 2. Percentage composition of the AC 16W mix

Material	Rock name, Binder, Additive	AC 16W 35/50 Percentage [%] Mineral Mixture (w/w)	AC 16W 35/50 Percentage [%] Mineral-Asphalt Mixture (w/w)
Aggregate 8/16 mm	Dolomite	37.0	35.4
Aggregate 2/8 mm	Dolomite	25.0	23.9
Aggregate 0/4 mm	Dolomite	36.0	34.4
Limestone filler	Limestone	2.0	1.9
Bitumen 35/50	–		4.4
Adhesive			0.1
Total			100.0

This design of the mineral-asphalt mixture compositions ensures the stability of the mixtures and allows for a clear assessment of the effect of basalt fibers on the properties of asphalt concrete.

2.3. Experimental and Research Plan

The purpose of this article is to analyze the effect of dispersed reinforcement in the form of basalt fibers on the mechanical properties of asphalt concrete. The study focuses on evaluating the stiffness modulus and its variation over a wide temperature range from 5°C to 40°C. The experiment aims to determine the optimal percentage of fibers in the range from 0.5% to 1.5% to achieve the most favorable mechanical properties of asphalt concrete. Figure 3 presents a detailed experimental plan for the designed mineral-asphalt mixtures based on the amount of added fibers and the amount of additional asphalt.

The experimental design presented (Fig. 3) concerns the investigation of the properties of mineral-asphalt mixtures (AC 16W) with the addition of basalt fibers. The main objective of the study is to compare a reference sample with mixtures modified with different fiber contents (0.5% and 1.5%). The scheme also includes variants with added asphalt, which allows for an assessment of the binder's influence on the effectiveness of dispersed reinforcement within the asphalt concrete structure. This experimental design enables a precise determination of how the fiber dosage and adjustments to the asphalt content affect the technical parameters of the pavement.

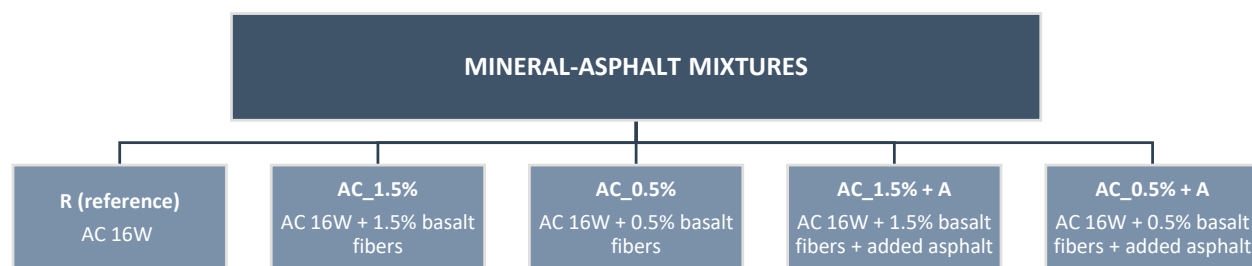


Fig. 3. Experimental setup for evaluating the effect of dispersed basalt fiber reinforcement on the stiffness modulus of asphalt concrete

Figure 4 shows the performance curves of the tested mixtures in terms of asphalt adjustment.

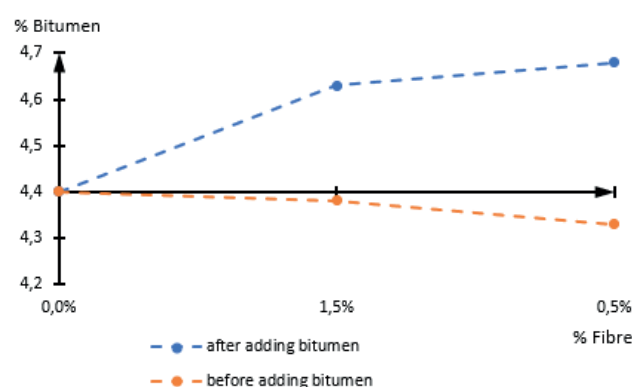


Fig. 4. Bitumen content in mixtures before and after binder adjustment

The envelope in Figure 4 represents the analyzed data range in terms of quantity. The starting point is the reference mix (0% fibers) with a bitumen content of 4.4%. The lower curve represents the change in the mixture's properties without accounting for asphalt adjustment, i.e., an increase in the fiber dosage, which results in a decrease in the amount of asphalt. At a dosage of 0.5% fibers, the asphalt content drops to 4.38%, while at 1.5% fibers, it decreases to 4.33%. In contrast, the upper curve represents the change in mixture properties taking into account the asphalt adjustment. After adding 0.3% asphalt to mixtures reinforced with basalt fibers, the total binder content increases. For the mixture with 0.5% fibers, this value is 4.68%, and for the variant with 1.5% fibers, it reaches 4.63%. To assess the impact of basalt fibers as reinforcement on the properties of asphalt concrete, a complete set of standard tests was conducted to determine whether the asphalt concrete mixtures meet the requirements of the guidelines [11, 12].

The scope of the tests on mineral-asphalt mixtures involved the evaluation of their physical, mechanical,

and volumetric properties, a summary of which, along with the relevant standards, is presented in Table 3.

Table 3. Tested parameters of the AC 16W

Tested parameter	Standard	Number of specimens and compaction conditions
Void characteristics of bituminous specimens (Va)	EN 12697-8 [13]	Number of specimens: 5 Compaction: Marshall compactor, 2 × 75 blows
Indirect tensile strength (ITSDRY)	EN 12697-23 [14]	Number of specimens: 5 Compaction: Marshall compactor, 2 × 75 blows
Water sensitivity of bituminous specimens (ITSR)	EN 12697-12 [15]	Number of specimens: 10 Compaction: Marshall compactor, 2 × 75 blows
Stiffness (IT-CY)	EN 12697-26 [16]	Number of specimens: 5 Compaction: Marshall compactor, 2 × 75 blows

After conducting the preliminary tests on the asphalt concrete, it was possible to proceed to the main phase of the study, which involved determining the stiffness modulus (S_m) in the IT-CY indirect tensile test on cylindrical specimens, carried out in accordance with the test method described in the PN-EN 12697-26 standard [16]. All specimens were prepared under laboratory conditions and compacted using a Marshall rammer, with 75 blows applied to each side (2 × 75) [18]. The specimens were conditioned at the test temperature prior to testing. The stiffness modulus an extremely important parameter for mixtures used in road pavement layers. To determine this parameter in the AC 16W mixture, a test was conducted using the IT-CY indirect tensile test method. The test was performed in accordance with the provisions of the PN-EN 12697-26 standard [16]. The horizontal displacement is $5 \pm 2 \mu m$, and the load rise time is 124 ± 4 ms.

The modulus of elasticity is determined using equation (1), and Poisson's ratio is determined using equation (2):

$$S_m = \frac{F \cdot (\nu + 0.27)}{z \cdot h} \quad (1)$$

$$\nu = 3.59 \cdot \frac{z}{\Delta V} - 0.27 \quad (2)$$

where:

- S_m – sample stiffness modulus [MPa];
- F – maximum force applied to the specimen [N];
- ν – the temperature-dependent Poisson's ratio;
- z – amplitude of the sample's horizontal displacement under load [mm];
- h – sample thickness [mm];
- ΔV – maximum vertical displacement of the specimen (corresponding to the maximum horizontal displacement) [mm].

When examining equation (2), a relationship should be noted. An increase in sample thickness and strain leads to a decrease in internal stress, which directly affects the stiffness modulus (S_m). The Figure 5 shows a test setup for determining the stiffness modulus using the IT-CY method.



Fig. 5. Test setup ready for stiffness modulus testing using the IT-CY method [W. Ściga]

3. ANALYSIS OF RESULTS

The assessment of the effect of basalt fiber reinforcement on the stiffness modulus of asphalt concrete was preceded by an evaluation of the basic properties, which are presented in Table 4.

Table 4. Results of basic tests on mineral-asphalt mixtures

Mixture name	V_m [%]	ITS _{DRY} [MPa]	ITSR [%]
R (reference)	5.9	1.382	98
AC_1.5%	3.9	1.734	97
AC_0.5%	6.9	1.746	91
AC_1.5% + A	6.4	0.768	98
AC_0.5% + A	5.6	1.508	94

When comparing the results of the reference mixture (R) with the other variants modified with basalt fibers, it can be observed that the highest indirect tensile strength (ITS_{DRY}), exceeding 1.7 MPa, was achieved by the AC_1.5% and AC_0.5% mixtures. In turn, the addition of asphalt to the mineral-asphalt mixtures, designated as “+ A,” significantly influenced the material properties, which is particularly evident in the case of the AC_1.5% + A mixture. This variant achieved a void content of 6.4% and the lowest indirect tensile strength, equal to 0.768 MPa. Despite these differences in void content and indirect tensile strength, most of the tested samples exhibited very good water resistance, as the ITSR index for all mixtures remained at a high level ranging from 91% to 98%.

To conduct a detailed analysis of the mechanical properties, the stiffness modulus was determined using the IT-CY indirect tensile test at three temperatures 5°C, 25°C, and 40°C in accordance with the PN-EN 12697-26 standard [16].

Figure 6 shows the results of the stiffness modulus determined using the indirect tensile method for the three temperatures tested.

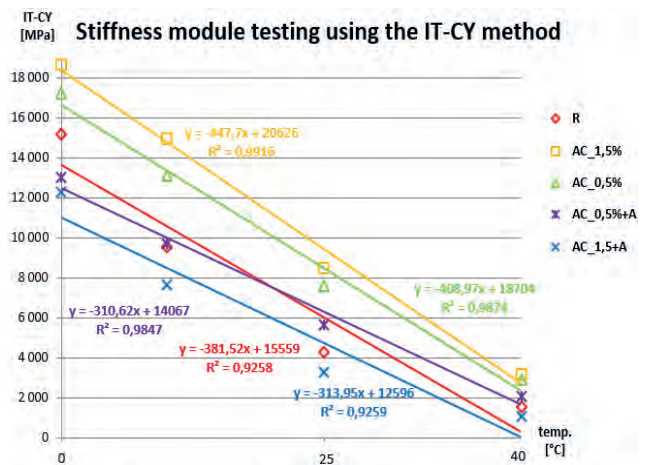


Fig. 6. Results of the S_m (IT-CY) stiffness modulus as a function of temperature

The stiffness modulus results determined using the IT-CY method revealed a clear correlation with the temperature at which the test was conducted. The highest values were recorded at 5°C, while the lowest were at 40°C, indicating a shift in the ratio between the elastic and viscous responses of the material at high temperatures. The results for the mineral-asphalt mixture with 1.5% basalt fibers and additional asphalt (AC_1.5%+A) showed the lowest stiffness at each of the analyzed temperatures. In contrast, the highest results at each tested temperature were recorded for the mineral-asphalt mixture with an additional 1.5% basalt fibers (AC_1.5%). The graph presents an analysis of the thermal sensitivity of the mixtures, where the coefficients for the variable “x” determine the rate of decrease in the stiffness modulus as temperature increases.

To assess the rate of change of the stiffness modulus, the coefficient “a” of the linear equation was analyzed. The results are presented in Table 5.

Table 5. Summary of the rates of change in the stiffness modulus

	a	b	R ²
R (reference)	398.93	16311	0.9379
AC_1.5%	444.59	20491	0.9908
AC_0.5%	413.26	18889	0.987
AC_1.5%+A	313.95	12596	0.9259
AC_0.5%+A	316.01	14300	0.9858

The highest value of this parameter, $a = 444.59$, was recorded for the AC_1.5% mixture, which means that it reacts most violently to thermal changes. In contrast, mixtures with additional asphalt (designated as AC_1.5%+A and AC_0.5%+A) exhibit significantly lower values of the a parameter, indicating greater stability and lower susceptibility to the effects of rising temperatures. The AC_1.5%+A mixture proved to be the most resistant to changes, with a coefficient of just $a = 313.95$. This comparison demonstrates that increasing the amount of asphalt effectively “smooths out” the material’s characteristics, limiting the rate of stiffness loss.

To observe and compare changes in the stiffness of asphalt concrete containing basalt fibers across different temperature ranges, the average results for the analyzed AC mixtures are presented in Figures 7-9.

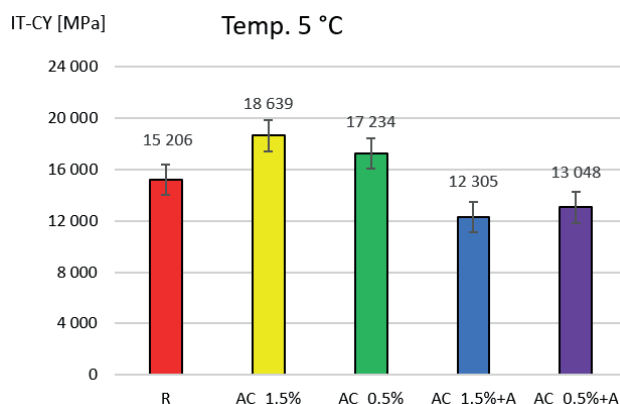


Fig. 7. Bar chart showing the IT-CY stiffness modulus at 5°C (the error bars indicate the standard deviation)

Figure 7 shows the IT-CY stiffness modulus values of the tested mixtures at a temperature of 5°C. The highest result (18.639 MPa) was obtained by the AC_1.5% mixture. The use of basalt fibers alone significantly increased the stiffness of the material compared to the reference mixture, suggesting improved stiffness under temperature conditions fluctuating around 5°C. However, a drastic decrease in stiffness is noticeable in the variants with additional asphalt (AC_1.5%+A and AC_0.5%+A), particularly in the case of the AC_1.5%+A mixture, which achieved the lowest value (12.305 MPa). This comparison of results shows that while fibers stiffen the structure, excess binder significantly increases the mixture’s flexibility, which may protect the pavement against low-temperature cracking.

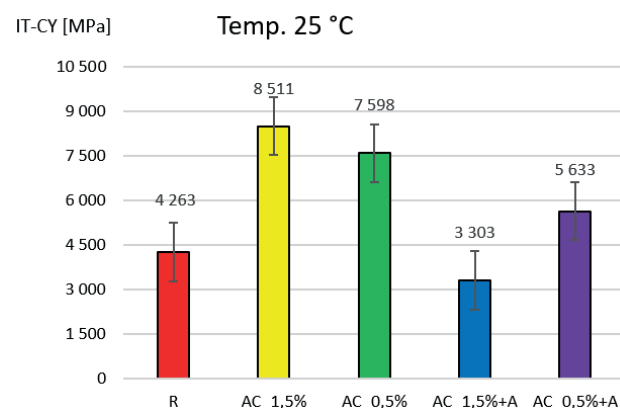


Fig. 8. Bar chart showing the IT-CY stiffness modulus at 25°C (the error bars indicate the standard deviation)

At 25°C, mixtures containing only basalt fiber additives (AC_1.5% and AC_0.5%) exhibit a modulus of stiffness nearly twice as high as that of the reference mixture, confirming their reinforcing effect on the structure. As at lower temperatures, the addition of asphalt

(AC_1.5%+A and AC_0.5%+A) results in a significant reduction in stiffness, with the AC_1.5%+A mixture achieving the lowest value of 3.303 MPa. These results demonstrate that the fibers effectively stiffen the mineral matrix at service temperatures, while adjusting the binder content allows for flexible tuning of the final mixture parameters. The error bars presented indicate varying repeatability of the results, particularly evident in the case of the softest variants.

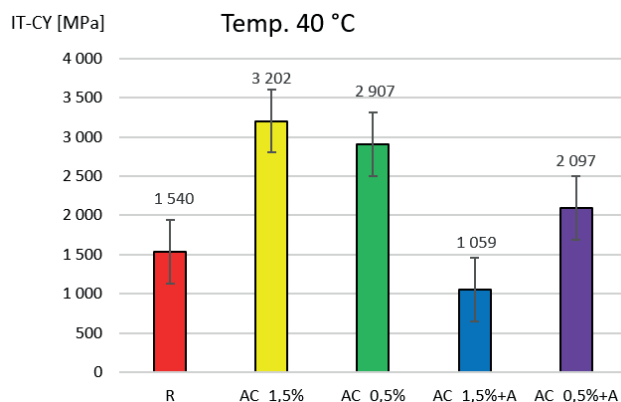


Fig. 9. Bar chart showing the IT-CY stiffness modulus at 40°C (the error bars indicate the standard deviation)

At a high temperature of 40°C (Fig. 9), the stiffness modulus of all mixtures decreased naturally; however, the fiber-reinforced variants (AC_1.5% and AC_0.5%) still maintained a significant advantage over the reference sample. The highest stiffness (3.202 MPa) was retained by the mixture with the highest fiber content (AC_1.5%), which confirms their key role in limiting permanent deformation under high pavement temperatures. In contrast, the AC_1.5%+A mixture achieved the lowest value (1.059 MPa), indicating this mixture's high susceptibility to high temperatures when the binder content is excessive. The graph as a whole demonstrates that optimal dosing of basalt fibers without excessively increasing the amount of asphalt yields the most durable structure under summer conditions.

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4. CONCLUSIONS

Based on an analysis of test results for basalt fiber-reinforced mineral-asphalt mixtures, the following conclusions were drawn:

- The addition of 0.5% and 1.5% basalt fibers significantly increases the stiffness modulus of asphalt concrete compared to the reference mixture. The highest IT-CY values at each tested temperature were obtained for the mixture containing 1.5% fibers (AC_1.5%), confirming their effectiveness in stiffening the mineral-asphalt mixtures.
- Adjusting the binder content (AC_1.5%+A and AC_0.5%+A) results in a significant decrease in the stiffness modulus at all analyzed temperatures. These mixtures are characterized by greater deformability, which may affect the pavement's resistance to fatigue and low-temperature cracking.
- Based on the derived equations, it was found that fiber-reinforced mixtures (AC_1.5% and AC_0.5%) exhibit the highest thermal sensitivity (the highest "a" values). In contrast, the variants with additional asphalt (AC_1.5%+A and AC_0.5%+A) exhibit a significantly slower rate of stiffness decline as temperature increases, indicating greater stability of their parameters across a wide range of operating temperatures.
- In all cases analyzed, the modulus of elasticity decreases as the test temperature increases, which is typical for viscoelastic materials. However, even at 40°C, mixtures containing only fiber additives (AC_1.5% and AC_0.5%) retain nearly twice the stiffness of the reference sample (R – AC 16W), which may reduce the pavement's susceptibility to rutting.
- The results indicate that the mere addition of basalt fibers effectively stiffens the asphalt concrete structure, which is desirable in terms of rutting resistance; however, the addition of asphalt can be used to improve low-temperature cracking resistance at the expense of the layer's overall stiffness.

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TRANSFORMATION OF THE ADVERTISING LANDSCAPE AND LANDSCAPE GOVERNANCE IN A HISTORIC CITY CENTRE: THE CASE OF KIELCE (POLAND)

PRZEKSZTAŁCENIA KRAJOBRAZU REKLAMOWEGO I ZARZĄDZANIA KRAJOBRAZEM W HISTORYCZNYM CENTRUM MIASTA: PRZYPADEK KIELC (POLSKA)

Jagoda Juruś*, Julia Lech
Kielce University of Technology, Poland

Abstract

The rapid expansion of outdoor advertising in post-socialist cities has transformed the visual structure of historic urban landscapes, contributing to visual pollution. This study investigates the transformation of the advertising landscape in the historic city centre of Kielce (Poland) and evaluates the effectiveness of landscape governance in improving visual quality and spatial order. The research combines a literature review, historical analysis, planning document analysis, field observations, and a semi-quantitative comparative visual assessment of selected building facades. The results indicate that historical forms of advertising were generally better integrated with architectural composition, whereas post-1989 advertising contributed to visual fragmentation. The implementation of the 2022 landscape resolution reduced advertising density, improved architectural visibility, enhanced visual coherence, and increased the transparency of ground-floor facades. The findings demonstrate that local landscape governance can effectively reduce visual pollution and support the sustainable management of historic urban environments.

Keywords: visual pollution; landscape governance; advertising landscape; historic urban landscape; urban sustainability; spatial order; outdoor advertising; cultural heritage

Streszczenie

Gwałtowny rozwój reklamy zewnętrznej w miastach postsocjalistycznych przekształcił wizualną strukturę historycznych krajobrazów miejskich, przyczyniając się do powstania zanieczyszczenia wizualnego. Niniejsze badanie analizuje przemiany krajobrazu reklamowego w historycznym centrum Kielc (Polska) oraz ocenia skuteczność działań w zakresie zarządzania krajobrazem pod kątem poprawy jakości wizualnej i ład przestrzennego. Metodologia badań obejmuje przegląd literatury, analizę historyczną, analizę dokumentów planistycznych, obserwacje terenowe oraz półilościową, porównawczą ocenę wizualną wybranych elewacji budynków. Wyniki wskazują, że historyczne formy reklamy były zazwyczaj lepiej wkomponowane w kompozycję architektoniczną, podczas gdy reklamy powstałe po 1989 roku przyczyniły się do fragmentacji wizualnej przestrzeni. Wdrożenie uchwały krajobrazowej z 2022 roku doprowadziło do zmniejszenia zagęszczenia reklam, poprawy widoczności architektury, zwiększenia spójności wizualnej oraz poprawy przejrzystości elewacji na poziomie parteru. Uzyskane wyniki dowodzą, że lokalne zarządzanie krajobrazem może skutecznie ograniczać zanieczyszczenie wizualne i wspierać zrównoważone gospodarowanie historycznymi przestrzeniami miejskimi.

Słowa kluczowe: zanieczyszczenie wizualne; zarządzanie krajobrazem; krajobraz reklamowy; historyczny krajobraz miejski; zrównoważony rozwój miast; ład przestrzenny; reklama zewnętrzna; dziedzictwo kulturowe

1. INTRODUCTION

Contemporary cities are characterised by an intensive presence of various forms of visual communication, which constitute an integral component of the urban landscape. Outdoor advertising plays an important informational and economic role, enabling businesses to communicate with potential customers and supporting local economic development. At the same time, its excessive expansion may lead to significant aesthetic and functional problems in public space. In urban studies, this phenomenon is commonly referred to as visual pollution [1].

Visual pollution is defined as an excess of visual elements that disrupt spatial perception, hinder orientation within the city, and reduce the overall quality of the urban environment [2]. The most frequently identified sources of this phenomenon include large-format advertisements, chaotically arranged shop signs, banners, and other forms of commercial visual communication. This issue is particularly evident in historic city centres, where intensive commercial and service activities result in a high concentration of advertising elements within spaces of significant cultural and architectural value.

Previous studies conducted in various countries indicate that an excessive number of advertisements may lead to the degradation of cultural landscapes and a reduction in the legibility of urban composition [1]. Nevertheless, advertising remains an essential component of urban space and cannot be entirely eliminated. Therefore, increasing attention is being paid to finding a balance between market-driven economic needs and the protection of public space quality.

The problem of advertising-related visual disorder became particularly pronounced in Central and Eastern European cities following the political and economic transformation after 1989. The liberalisation of the economy and the rapid development of the private sector led to a significant increase in outdoor advertising. In many cases, this process occurred in the absence of adequate legal regulations governing the placement and form of advertising media, resulting in a noticeable deterioration in the visual quality of urban environments [3].

In response to the growing problem of visual clutter, Poland introduced the so-called “Landscape Act” in 2015, which enabled local governments to adopt landscape resolutions regulating the location, size, and aesthetic standards of advertising in public space. In recent years, an increasing number of Polish cities have implemented such regulations as part of

broader urban landscape governance strategies aimed at improving spatial quality and protecting cultural landscapes.

One example is the city of Kielce, where a landscape resolution was adopted in 2022, regulating the placement of advertisements, shop signs, fences, and elements of street furniture. The regulation introduced a division of the city into landscape zones and defined detailed requirements regarding the form and location of advertising media. These provisions are particularly important in the historic city centre, where the concentration of commercial activities generates strong advertising pressure on building facades.

Despite the growing academic interest in visual pollution and the impact of advertising on urban landscapes, empirical evidence focusing on medium-sized cities in Central and Eastern Europe remains limited. Existing research has predominantly concentrated on large metropolitan areas or on theoretical approaches to visual pollution and its assessment methods. Nevertheless, there is a clear lack of in-depth analyses evaluating the actual spatial effects of local landscape regulations, particularly in historic urban environments.

Moreover, the transformation of advertising landscapes in post-socialist cities – from historically integrated forms of visual identification, such as traditional shop signs and neon signage, to contemporary large-scale advertising and fragmented visual communication systems – remains insufficiently explored. Understanding these processes is crucial not only from the perspective of urban aesthetics but also in terms of cultural heritage protection, spatial order, and the construction of urban visual identity.

From a sustainability perspective, visual quality and landscape coherence are increasingly recognised as important components of sustainable urban development. Addressing visual pollution and improving the legibility of urban space contribute to enhancing the liveability and cultural value of cities. In this context, local regulatory instruments can play a key role in shaping more sustainable and visually coherent urban environments.

Therefore, the aim of this study is to analyse the transformation of the advertising landscape in the historic city centre of Kielce and to assess the role of the landscape resolution as an instrument of urban landscape governance and visual order improvement. The research focuses on identifying historical and contemporary transformations of the advertising landscape and evaluating changes in the visual

structure of selected building facades following the implementation of landscape regulations.

The novelty of this study lies in combining a long-term historical perspective on advertising forms with a comparative visual assessment of facade transformations resulting from the implementation of landscape governance tools in a medium-sized post-socialist city. Unlike previous studies focused primarily on large metropolitan areas or theoretical approaches to visual pollution, this research provides empirical evidence on how local regulatory frameworks influence architectural visibility, visual coherence, and spatial order in historic urban environments. The study also contributes to broader discussions on the role of landscape governance in sustainable urban landscape management.

2. THEORETICAL BACKGROUND: ADVERTISING IN THE STRUCTURE OF THE URBAN LANDSCAPE

2.1. Advertising within the Cultural Landscape

Advertising constitutes a persistent and multifaceted component of the contemporary urban landscape. Its impact extends beyond its informational function, influencing spatial perception, place identity, visual order, and the overall quality of the cultural environment. In the scientific literature, advertising is analysed both within the framework of the cultural landscape and more broadly as a factor contributing to so-called visual pollution. This section presents a synthetic theoretical overview based on established models of spatial analysis and studies examining the impact of commercial visual interventions on urban structures.

The urban landscape is a multi-layered structure resulting from the interaction of physical form, functional processes, and cultural meanings. According to the literature, urban space consists of overlapping layers: the physical (urban form), the functional (urban activity), and the symbolic (meaning layer) [4, 5]. Advertising – as a visual communication medium – operates within this symbolic layer, acting as a cultural inscription that both interprets and transforms place.

Within the concept of the cultural landscape, as developed by Sauer and later expanded by Cosgrove, advertising can be understood as a form of semantic inscription embedded in space. It contributes to the legibility of the environment by emphasising commercial and service-related functions [4]. At the same time, it may obscure the visual structure of urban space by competing with architectural elements of historical value.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) emphasises that in historic areas – particularly those protected under the Historic Urban Landscape (HUL) approach – visual interventions should be carefully controlled to avoid compromising heritage values. Due to its dynamic and often temporary character, advertising is considered one of the most significant threats to the integrity of historic urban landscapes [1, 6].

2.2. Advertising as a Perceptual Stimulus – An Environmental Psychology Perspective

In theoretical models of environmental perception [7, 8], it is emphasised that an excessive number of visual stimuli reduces spatial orientation and increases cognitive load. Advertising – by definition designed to attract attention – competes with architectural space for the viewer's visual focus. These mechanisms are particularly relevant in historic urban environments, where excessive advertising may interfere with the perception of architectural composition and reduce the legibility of cultural landscapes.

Empirical studies have demonstrated that:

- an excess of advertising reduces the perceived quality of the landscape [9],
- compositionally dominant advertisements alter the visual structure and disrupt the perception of architectural detail [10],
- dynamic LED screens change the rhythm of nighttime urban space and may lead to sensory overload [11].

The presence of advertising along commercial streets has a particularly strong impact on the perception of linear urban sequences. This has been investigated using eye-tracking methods, which show that users' visual attention is primarily drawn to dynamic and high-contrast stimuli [12].

2.3. Advertising and Visual Pollution

The concept of visual pollution has been widely analysed in interdisciplinary research. According to the systematic review by Gao et al. [1], visual pollution has been described in the literature as elements that disrupt the landscape through excess, low aesthetic quality, inappropriate scale, or lack of contextual coherence.

Commercial advertising is one of the primary contributors to visual disorder in urban environments, leading to:

- fragmentation of visual composition,
- dominance of ephemeral elements over enduring historical values,

- reduced legibility of public space,
- difficulties in perceiving protected architectural heritage.

These effects are particularly pronounced in historic areas, where the protection of visual corridors, skylines, and architectural detail is essential.

2.4. Economic and Functional Roles of Advertising

From an economic perspective, advertising is embedded within the logic of consumption and capitalist models of urban development [13]. In commercial and service-oriented areas, it plays an important informational role, enhancing business visibility and indicating location.

However, the literature also highlights that increasing commercial pressure leads to conflicts between private economic interests and the public interest, particularly in maintaining spatial order and protecting historical values [14]. These conflicts are especially evident in heritage areas, where advertising must be subject to stricter regulations.

From the perspective of sustainable urban development, these conflicts reflect the broader challenge of balancing economic activity with the preservation of environmental quality and cultural heritage within urban landscapes.

2.5. The Positive Role of Advertising in Urban Landscapes

The literature also acknowledges that advertising can have positive effects. It may contribute to the visual identity of commercial streets [15], create distinctive aesthetic atmospheres – particularly in nighttime environments (so-called media architecture) [16] – and, in some cases, become part of cultural heritage. Examples include historic neon signage in cities such as Warsaw, Berlin, and Prague [17].

The concept of the heritage of modernity suggests that certain forms of advertising – especially mid-20th-century neon signs – can be recognised as valuable cultural artefacts [18].

In this context, advertising should not be perceived solely as a source of visual degradation but also as a potential component of sustainable urban identity, provided that it is appropriately integrated into the architectural and cultural context.

The theoretical concepts discussed above – particularly visual coherence, architectural visibility, spatial perception, and visual dominance – provide the conceptual basis for the comparative visual assessment applied in this study. These categories were used to evaluate transformations in the advertising

landscape following the implementation of landscape governance regulations in Kielce. The theoretical framework presented above also provides the basis for analysing the role of landscape governance tools in shaping visual order and improving the quality of historic urban environments.

3. METHODOLOGY

The aim of this study was to assess the transformation of the advertising landscape in the historic city centre of Kielce and to evaluate the impact of landscape regulations on visual order and spatial quality. The research was based on a qualitative and comparative approach combining literature review, historical analysis, field observations, photographic documentation, and comparative visual assessment.

3.1. Study Area

The research focused on the historic city centre of Kielce, with particular emphasis on Henryk Sienkiewicz Street – the city's main pedestrian street and one of its most important commercial axes. This street constitutes a representative public space characterised by a high concentration of commercial, retail, and gastronomic functions, resulting in intensive advertising pressure and a large number of visual communication elements.

The study area included selected fragments of the historic city centre characterised by high historical and urban value and a strong concentration of commercial activities. The selection of this location was based on its representativeness for the visual structure of the city centre and the significant intensity of advertising observed on building facades.

The location of the study area and the analysed case studies within the historic city centre of Kielce are presented in Figure 1.



Fig. 1. Location of the study area and analysed case studies within the historic city centre of Kielce, Poland

3.2. Literature and Planning Document Analysis

The first stage of the research involved a review of the literature concerning the impact of advertising on urban landscapes and the phenomenon of visual pollution. The literature review included publications in urban studies, landscape architecture, environmental psychology, and cultural landscape research, as well as scientific articles analysing the influence of outdoor advertising on spatial perception and visual quality.

At the same time, planning documents and legal acts regulating the placement of advertisements in Poland and in Kielce were analysed, in particular:

- the Spatial Planning and Development Act,
- the Landscape Act (2015),
- the landscape resolution of the city of Kielce adopted on 21 April 2022.

The analysis made it possible to define the legal framework governing the location and form of advertising media and to identify instruments used in urban landscape governance and visual order management.

3.3. Historical Analysis

The next stage of the research involved an analysis of the historical development of signage and advertising in the urban space of Kielce. The study was based on archival photographs, iconographic materials, historical documentation, and studies related to the spatial and commercial development of the city.

The analysis enabled the identification of changes in forms of outdoor advertising across different historical periods, with particular emphasis on:

- craft and commercial signage from the late 19th and early 20th centuries,
- advertising and graphic design from the interwar period,
- neon signage characteristic of the socialist period,
- contemporary forms of outdoor advertising following the political and economic transformation after 1989.

This approach allowed for the presentation of long-term transformations in the advertising landscape and changes in the relationship between advertising and architectural composition.

3.4. Spatial Analysis of the Advertising Landscape

A spatial analysis was conducted for selected areas of the city centre, with particular focus on

Sienkiewicz Street and adjacent public spaces. The analysis included the identification of advertising types, their spatial distribution, placement, scale, and visual characteristics.

The study employed field observation and photographic documentation of changes in the urban landscape. This method is commonly applied in urban landscape and visual assessment studies as a tool for evaluating the visual quality of public space.

The analysis focused on the spatial structure and visual impact of advertising elements, including their number, scale, placement, visual dominance, and relationship with architectural composition. Particular attention was given to facade legibility, visual coherence, and the transparency of ground-floor zones.

3.5. Comparative Visual Assessment

A semi-quantitative comparative visual assessment was carried out to evaluate changes in the advertising landscape following the implementation of the landscape resolution. The assessment focused on selected building facades located along Sienkiewicza Street and was based on a comparison of archival and contemporary photographic documentation collected during field observations.

Five representative case studies were selected according to the following criteria:

1. Location along the main commercial axis of the historic city centre (Sienkiewicza Street);
2. High visibility within the public space;
3. Representativeness of different types of advertising landscape transformation, including the elimination, reduction, and standardisation of advertising elements;
4. Availability of comparable archival and contemporary photographic documentation illustrating the conditions before and after the implementation of the landscape regulations.

The assessment was conducted using a semi-quantitative evaluation framework commonly applied in landscape studies and visual quality assessment. Five evaluation criteria were adopted:

- advertising density,
- architectural visibility,
- visual coherence,
- ground-floor transparency,
- visual dominance.

Each criterion was evaluated using a five-point ordinal scale, in which higher scores represented

more favourable visual conditions. For advertising density, higher scores indicated a lower concentration of advertising elements, whereas for the remaining criteria higher scores reflected improved architectural visibility, greater visual coherence, increased ground-floor transparency, and the predominance of architecture over advertising.

The visual assessment was carried out independently by both authors using the predefined evaluation criteria presented in Table 1. Any differences in interpretation were subsequently discussed until a consensus was reached, ensuring consistency in the final assessment.

The adopted methodology combined descriptive interpretation with a semi-quantitative visual assessment, enabling the identification of changes in advertising density, architectural visibility, visual coherence, ground-floor transparency, and visual dominance before and after the implementation of the landscape resolution. The analysis focused on changes in facade composition, the relationship between advertising and architecture, and the overall visual structure of the streetscape.

The assessment criteria and interpretation scale applied in the comparative visual analysis are presented in Table 1.

Table 1. Assessment criteria applied in the comparative visual analysis

Criterion	1	3	5
Advertising Density	Very high density	Moderate density	Minimal advertising
Architectural Visibility	Architecture obscured	Partially visible	Fully visible
Visual Coherence	Chaotic composition	Moderate coherence	Highly coherent
Window Transparency	Covered windows	Partial transparency	Fully transparent
Visual Dominance	Advertising dominant	Balanced	Architecture dominant

Note: Intermediate values (2 and 4) represent transitional conditions between the anchor points defined in the assessment scale.

The overall research workflow applied in this study is presented in Figure 2.

THE PROBLEM: The Impact of Outdoor Advertising on the Landscape of the Historic City Center.

RESEARCH PURPOSE: Assessment of the impact of advertising and the effectiveness of landscape regulations

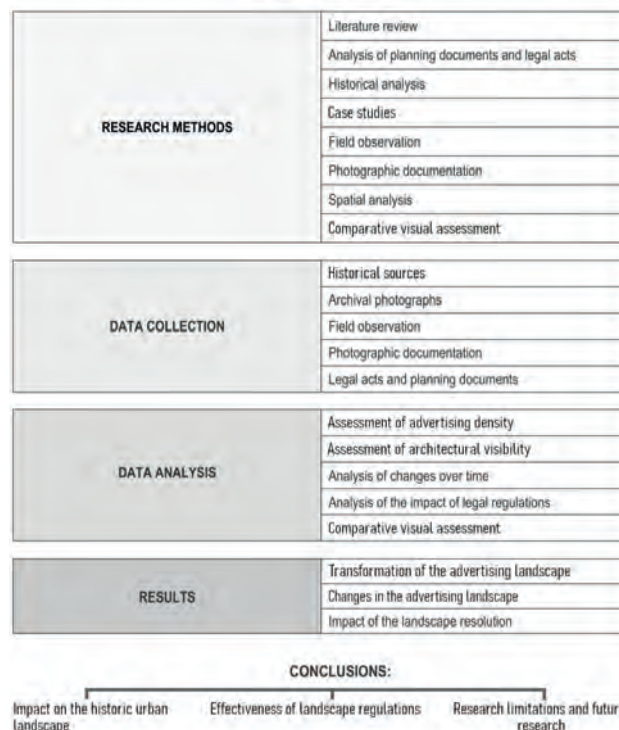


Fig. 2. Research workflow

4. HISTORICAL DEVELOPMENT OF SIGNAGE AND ADVERTISING – FROM GENERAL CONTEXT TO THE LOCAL CASE OF KIELCE

4.1. Historical and Theoretical Development of Signage and Advertising

Advertising, understood as visual commercial communication, has been an integral component of the urban landscape since the intensification of urbanisation processes in the 19th century. The development of retail trade, craft services, and industrial production created the need for clear identification of business locations, which led to the widespread use of signs and advertising boards in European cities. Studies on urban landscape formation indicate that advertising elements functioned not only as commercial messages but also as important components of the visual identity of streets and districts [19].

In Poland, the interwar period brought a dynamic development of graphic design reflected in signage, posters, and advertisements painted directly on building facades. These designs were often created by professional artists and were characterised by a high

level of compositional and typographic awareness [20]. Neon signs also played a significant role as symbols of modernity, appearing in major Polish cities as early as the 1930s.

After World War II, during the socialist period, illuminated advertising was centralised under the state enterprise “Reklama”, which from the late 1950s was responsible for the design, production, and installation of neon signs across the country [21, pp. 7–10]. Neon signage fulfilled a dual function: informational and commercial on the one hand, and representational on the other, contributing to the visual attractiveness of urban space, especially at night [21, pp. 7–10].

Since the 1990s, traditional neon signage has gradually disappeared due to both political-economic transformation and the introduction of cheaper advertising technologies, such as vinyl banners and plastic light boxes. Literature in architecture and urban studies indicates that this process resulted in the loss of an important cultural and aesthetic layer of the urban landscape [23, pp. 34–40]. In many post-socialist cities, context-sensitive and architecturally integrated forms of visual communication were replaced by fragmented and commercially dominant advertising systems.

In recent years, however, renewed interest in neon signage has emerged, with such elements increasingly recognised as part of urban cultural heritage and carriers of place identity. From the perspective of urban sustainability, this shift highlights the tension between economically driven visual transformation and the preservation of culturally embedded landscape elements.

The historical evolution of advertising demonstrates a broader transformation of urban visual culture – from architecturally integrated forms of communication towards increasingly commercialised and spatially dominant advertising systems. This process reflects wider socio-economic transformations affecting post-socialist cities and highlights the growing tension between commercial visibility and the preservation of cultural landscape values.

4.2. Historical Development of Signage and Advertising in Kielce

The economic development of Kielce accelerated following the opening of the railway line in the 1880s and the rapid expansion of the quarrying and lime industry associated with the exploitation of Devonian limestone deposits at Kadzielnia and Wietrznia. The growth of industrial, commercial, and service activities contributed to the increasing importance of the city

[24, pp. 11–18]. As commercial activity expanded, signs and other forms of visual identification became increasingly common in urban space. Painted signs on wooden boards and directly on building facades were commonly used, reflecting practices observed in many Polish cities of that period.

During the interwar period, Kielce followed broader national trends observed in cities such as Warsaw, Łódź, and Kraków, where signage design evolved in line with modern graphic design principles. Signs frequently included the owner’s name, reflecting contemporary commercial culture. Archival photographs from the historic centre also show bilingual signage (Russian and Polish), illustrating the socio-political context of the period (Figs. 3–6). Local workshops produced enamel plates and typographic signage consistent with interwar design trends.



Fig. 3. Shopfront of Karol Soczek’s Optical and Mechanical Workshop in Kielce – example of late 19th-century commercial signage integrated with the architectural composition of the facade [25]



Fig. 4. Bilingual sign of the Mutual Life Insurance Company “New York”, Kielce, Konstantego Street – example of multilingual commercial communication in the pre-independence urban landscape [26]



Fig. 5. Archival photograph of J. Kotowski's wine store – Kielce, Sienkiewicza Street. Advertisement painted directly on the gable wall of the building, illustrating early forms of large-scale facade advertising integrated into the streetscape [26]



Fig. 6. Signage of J. Kotowski's delicatessen after Poland regained independence (Kielce, Sienkiewicza/Duża Street), demonstrating the transformation of visual communication in the interwar commercial landscape [26]

In the 1960s and 1970s, Kielce participated in the nationwide process of urban “neonisation”. Approximately 200 neon signs were in operation in Kielce during the 1970s [27]. Many of the most prominent installations were located along Sienkiewicza Street, the city’s main commercial and representative thoroughfare. These installations served both informational and aesthetic functions, enhancing the attractiveness of urban space after dark and contributing to the city’s visual identity [21, pp. 7-10].

The character of Kielce’s neon signage (Figs. 7-8) corresponded to the broader typology of socialist-era neon design. Many of them were based on standardised designs produced by the “Reklama” enterprise, while others were locally designed, often combining functional clarity with expressive graphic forms. Studies on neon signage in Poland suggest that such realisations formed an important part of the visual culture of the period, characterised by simplified yet visually distinctive compositions [23, pp. 34-37; 27].

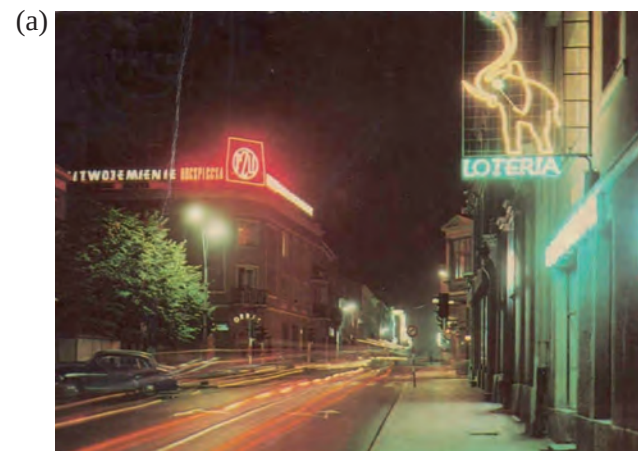


Fig. 7. Example of architecturally integrated neon signage characteristic of the socialist-period visual identity of Kielce – “Loteria” neon sign located on Sienkiewicza Street (a) and its design documentation (b) [26, 28]

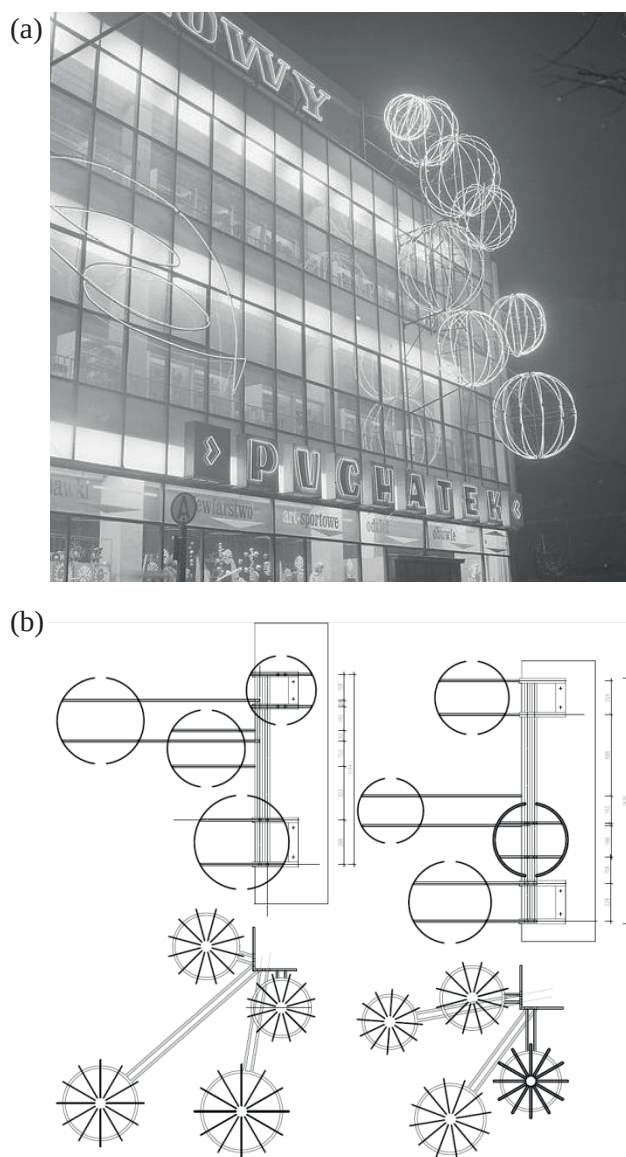


Fig. 8. “Puchatek” Department Store on Sienkiewicza Street – example of modernist commercial architecture integrated with spatial neon signage (a) and neon design documentation (b) [26, 28]

The economic transformation of the 1990s led to the dominance of low-cost advertising forms, such as vinyl banners, adhesive films, and plastic light boxes. During this period, many neon signs in Kielce – similarly to other Polish cities – were dismantled, deactivated, or fell into disrepair. These new advertising forms contributed to the fragmentation and visual degradation of the urban landscape, widely described in the literature as visual pollution [1].

The uncontrolled expansion of low-cost advertising media contributed to the progressive fragmentation of facade composition and the deterioration of visual coherence within the historic city centre.

These processes became one of the key premises for introducing landscape governance instruments aimed at restoring spatial order and protecting the visual identity of the city.

In the last decade, renewed interest in neon signage has emerged, with increasing recognition of its value as cultural heritage and an element of local identity. Recent studies indicate that historic neon signs are increasingly perceived not only as elements of twentieth-century design heritage but also as objects of collective memory and cultural tourism [18, pp. 46–49; 22]. In Kielce, such initiatives have been undertaken by local organisations, including the Society of Friends of Kielce, which has been involved in identifying, preserving, and promoting knowledge about historic neon signage.

This process reflects a broader shift towards integrating heritage preservation with sustainable urban landscape management. At the same time, preserving historic neon signs may contribute to reinforcing local identity and strengthening residents’ sense of place [5, pp. 45–66].

The combination of general and local perspectives demonstrates that the development of advertising in Kielce followed broader European and Polish trends while also exhibiting local specificity, particularly in the scale of neonisation, the character of signage, and its subsequent degradation.

The historical analysis indicates that earlier forms of advertising were generally more integrated with architectural composition and urban identity, whereas contemporary advertising systems increasingly contributed to visual fragmentation and spatial disorder. These observations provide the historical context for the comparative visual assessment presented in the following sections and justify the introduction of landscape governance instruments aimed at improving visual coherence and spatial order in the historic city centre.

5. LEGAL REGULATIONS ON ADVERTISING IN URBAN SPACE – THE CASE OF KIELCE

5.1. Landscape Regulations in Poland – The Landscape Resolution as a Tool for Urban Landscape Governance

The problem of excessive advertising in public space became particularly evident in Poland after the political transformation of the 1990s, when the rapid development of a market economy led to a significant increase in the number of advertising media in cities. The lack of coherent regulations regarding their

location, size, and form contributed to the emergence of what is described in the literature as advertising chaos or visual pollution [1]. This phenomenon resulted in the deterioration of public space aesthetics, reduced legibility of architecture, and degradation of the cultural landscape in many cities.

In response to the growing problem of visual disorder, the Polish legislator introduced the so-called Landscape Act (2015), amending the Spatial Planning and Development Act. This legislation enabled municipalities to adopt local regulations governing the placement of street furniture, fences, advertising boards, and advertising devices [29]. The new provisions made it possible to implement so-called landscape resolutions, which define rules and conditions for the placement of advertisements in public space, including permissible dimensions, forms of advertising media, quality standards for signage, and location restrictions.

The primary objective of landscape resolutions is to improve landscape quality, protect cultural and aesthetic values, and organise the visual structure of urban space. Such resolutions function as instruments of urban landscape governance, enabling municipalities to regulate visual quality, protect cultural landscapes, and restore spatial coherence within public space. These regulations allow for adapting advertising rules to the specific character of different urban areas by introducing landscape zones with differentiated requirements for historic, residential, commercial, or natural areas. This differentiated approach reflects the growing importance of context-sensitive landscape management in sustainable urban policy.

Studies on urban landscape management indicate that such regulatory frameworks can effectively reduce the negative effects of visual pollution and contribute to improving the aesthetics and legibility of urban space [10]. In urban studies literature, advertising is recognised as a key factor influencing spatial perception, and its excessive presence leads to landscape degradation and a decline in the quality of public space [19]. Therefore, advertising regulations are increasingly becoming a standard tool of urban policy in many European cities.

From the perspective of sustainable urban development, landscape resolutions can be understood as governance instruments that balance economic activity with the protection of cultural and visual environmental quality.

One example of such an approach is the city of Kielce, where a landscape resolution regulating the placement of advertisements has been implemented. The resolution introduces a division of the city into landscape zones with differentiated rules, representing a practical application of landscape governance at the local level.

5.2. The Landscape Resolution in Kielce

In Kielce, a landscape resolution was adopted to regulate the placement of advertising boards, advertising devices, signage, and elements of street furniture within the city.

The document introduces, among others:

- a division of the city into landscape zones,
- specific restrictions for advertising in areas of high cultural value,
- guidelines for signage design in historic areas,
- limitations on the size and form of advertising media.

Particular protection has been assigned to areas of high historical and urban value, including the city centre and representative public spaces. In these zones, stricter regulations regarding the size and form of signage were introduced in order to minimise the negative impact of advertising on the cultural landscape.

The introduction of advertising regulations in public space constitutes an important element of cultural landscape protection policy. Research indicates that limiting the number and scale of advertising media can significantly improve spatial legibility and enhance the perception of architectural values [30].

In the context of Kielce, the landscape resolution serves as a tool for organising the visual structure of the city, particularly in areas of high historical value, such as Sienkiewicz Street and the historic city centre.

The landscape resolution operationalises visual governance through the division of the city into four landscape zones (A–D) (Fig. 9), each characterised by different levels of advertising control depending on historical, functional, and landscape value [31]. These differences result from the varying cultural, spatial, and environmental characteristics of particular urban areas. The key regulatory principles for each zone are summarised in Table 2.

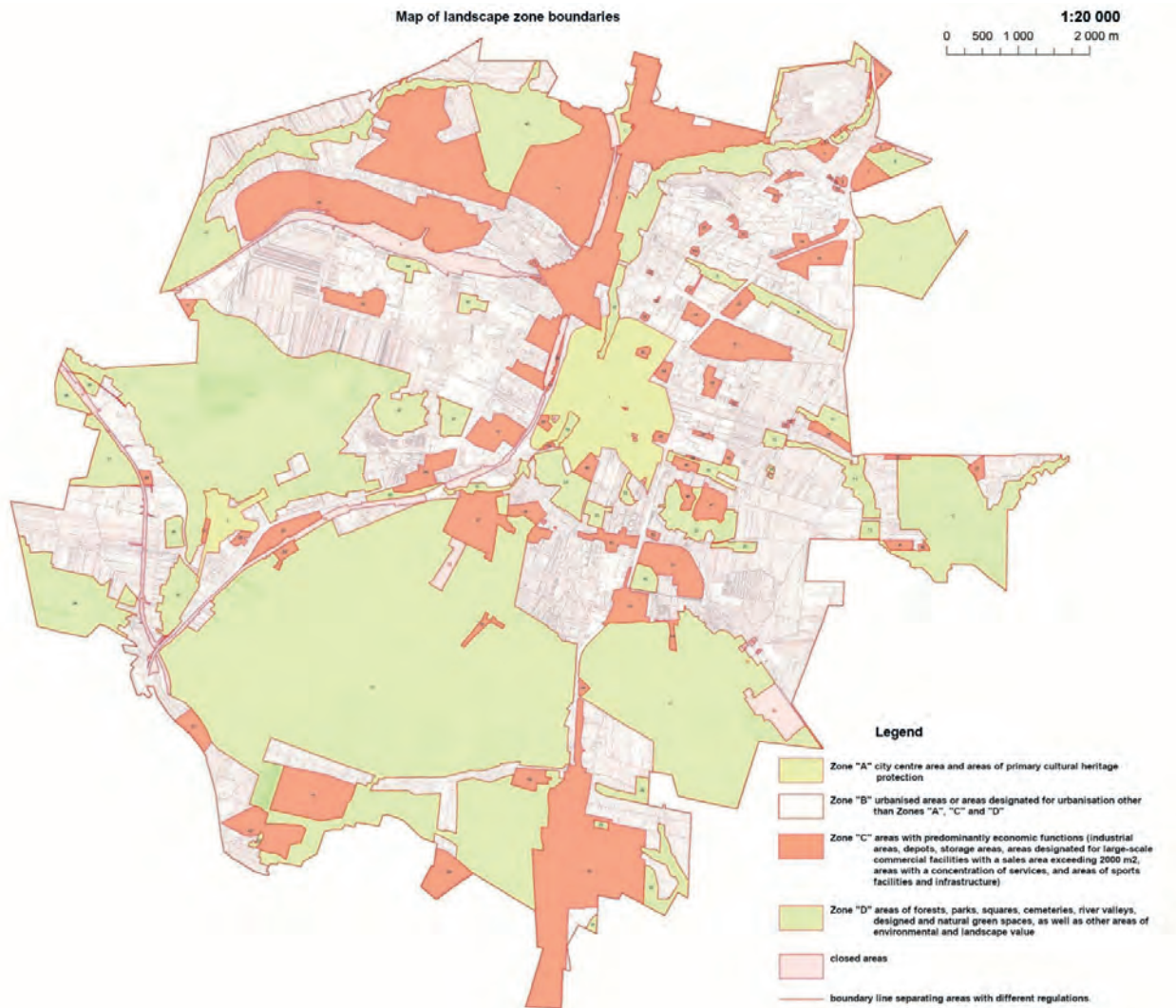


Fig. 9. Landscape zones (A–D) defined in the landscape resolution of Kielce, Poland [31]

Table 2. Landscape zones and advertising regulations in Kielce

Zone	Description	Key Regulations
Zone A – City Centre Area	Includes the historic city centre and areas of the highest cultural and architectural value. Subject to the most restrictive regulations to protect the historic urban fabric.	One sign per each commenced 30 m of facade; prohibition of covering architectural details (e.g., cornices, pilasters, window frames); strict control of form, size, and placement of signage.
Zone B – Areas of High Landscape Value	Includes areas with significant landscape value, such as urban green spaces and selected residential zones.	Maximum of two signs per each commenced 30 m of facade; regulations aim to balance economic activity with landscape protection.
Zone C – Remaining Urban Areas	Includes areas dominated by commercial, service, industrial, and sports functions.	Less restrictive regulations; greater flexibility in advertising placement; larger advertising media allowed, especially for commercial facilities (>2000 m ²).
Zone D – Environmentally Valuable Areas	Includes natural and landscape-sensitive areas such as forests, parks, river valleys, and cemeteries.	One sign per each commenced 30 m of facade; strict limitations to prevent visual dominance of advertising in natural landscapes.
General Regulations (All Zones)	Applies to all zones regardless of classification.	Prohibition of signage above ground floor level (except public buildings); restrictions on window coverings and adhesive graphics; requirement to maintain transparency of ground floors; regulation of fences and street furniture.

The zoning system reflects a hierarchical approach to visual landscape protection, with the strictest regulations applied to historically and visually sensitive urban areas. The differentiation of regulations across landscape zones directly influences the visual structure of urban space, which is reflected in observable changes in the advertising landscape.

5.3. Impact of the Landscape Resolution on the Urban Advertising Landscape

The introduction of the landscape resolution in Kielce represents a significant step towards organising the visual structure of the city and reducing advertising chaos. The regulations primarily aim to improve public space aesthetics, protect the cultural landscape, and enhance architectural legibility by limiting the number and size of advertising media.

One of the most notable effects has been the gradual removal of large-format advertising banners from building facades, particularly in the city centre. Before the implementation of regulations, banners often covered substantial parts of facades, obscuring architectural details such as cornices, window frames, and decorative elements. The new regulations contributed to revealing historic facades and improving architectural readability.

Another observable change is the gradual adaptation of signage to new requirements regarding size, location, and aesthetics. In many cases, large-scale signage has been replaced with smaller, more organised forms of visual identification. This has reduced visual clutter and improved spatial order along commercial streets. These transformations are particularly visible in facade composition, architectural readability, and the reduction of advertising dominance, as confirmed by the comparative visual assessment presented in the Results section.

Restrictions on window advertising have also contributed to increased transparency of ground floors and improved visual interaction between indoor commercial spaces and public space. This has important implications for urban quality, as transparent ground floors enhance pedestrian experience and perceived safety.

These changes can also be interpreted within the framework of sustainable urban design, where visual quality and human-scale perception are key components of livable public spaces.

It should be noted, however, that the implementation of the landscape resolution is a long-term process

requiring both administrative action and adaptation by property owners and businesses. In many cases, replacing existing signage involves additional costs, which is why transition periods are typically included in such regulations.

The landscape resolution can therefore be interpreted as an element of spatial policy aimed at improving urban landscape quality and reducing visual pollution. In the long term, such regulations may contribute to increased attractiveness of public spaces, improved aesthetics of the city centre, and strengthening of urban visual identity.

At the same time, the effectiveness of such regulations depends largely on consistent enforcement and cooperation between local authorities, business owners, and residents. Without proper supervision and educational efforts, legal regulations may not achieve the intended improvements in urban landscape quality.

The case of Kielce demonstrates how legal instruments can be used in urban landscape management to reduce advertising chaos. The differentiation of rules across landscape zones allows for context-sensitive regulation, contributing to improved spatial quality, visual coherence, and architectural legibility within the historic city centre.

The observed transformations demonstrate that landscape governance instruments can significantly influence the visual structure of historic urban environments. The spatial effects of these regulations are further examined through comparative facade analysis presented in the following section.

6. RESULTS

6.1. Spatial Structure of Advertising in the City Centre

The historic centre of Kielce is characterised by a high concentration of commercial and service functions, which translates into a high density of advertising media, including signage, advertising boards, banners, and other forms of visual communication. The greatest concentration of advertisements occurs along Henryk Sienkiewicz Street – the main pedestrian and commercial axis of the city.

Before the introduction of landscape regulations, this space exhibited a high diversity of advertising forms, including facade-mounted signage, vinyl banners, large-format advertisements, illuminated advertisements, and neon signs. The lack of unified design standards and the accumulation of visually competing elements contributed to the emergence of

visual chaos, reducing the legibility of architectural composition and negatively affecting the perception of public space [1].

The spatial structure of advertising was characterised by fragmented visual communication systems, inconsistent colour schemes, excessive window advertising, and the frequent use of large-format banners. In many cases, advertising elements dominated over architectural composition, particularly within ground-floor zones of commercial buildings.

6.2. Large-Format and Temporary Advertising

An important component of the advertising landscape consisted of large-format advertisements mounted on scaffolding during building renovations. These forms of advertising became widespread in Poland after the 1990s alongside the development of the advertising market and often utilised protective mesh as a medium for commercial communication.

This phenomenon is widely observed in many European cities and is often economically justified, as advertising revenues may support renovation works. However, the literature emphasises that large-scale advertisements placed on historic buildings can significantly reduce architectural readability and disrupt the perception of urban space [3].

In Kielce, large-format banners frequently covered substantial parts of facades, obscuring architectural details and visually transforming buildings into

temporary advertising surfaces. Such practices contributed to increased visual intensity and reduced the coherence of the historic streetscape.

6.3. Examples of Spatial Problems

One of the most recognisable examples of excessive advertising concentration in Kielce was the building located at 76 Sienkiewicza Street (Fig. 10), which in 2014 was ranked among the ugliest buildings in Poland in an online poll. The negative perception of this building was largely associated with the excessive number and scale of advertising boards and banners placed on the facade.

This example illustrates the mechanism of advertising chaos, in which individual commercial entities install separate advertising media without reference to architectural composition or urban context. As a result, the facade loses spatial coherence and architectural readability, while visual attention becomes dominated by commercial communication.

6.4. Comparative Visual Assessment of Facade Transformations

To assess the impact of the landscape resolution on the advertising landscape of the city centre, a comparative visual assessment was conducted for selected building facades located along Sienkiewicz Street. Five case studies were analysed based on archival and contemporary photographic documentation. Pre-regulation images were obtained



Fig. 10. Example illustrating the mechanism of advertising chaos – Kielce, 76 Sienkiewicza Street; upper floors fully covered by a large-format banner (a) [32], excessive concentration of advertisements at ground level (b) [33]

from the authors' archives and publicly available sources, while post-regulation conditions were documented by the authors.

The comparison of visual materials revealed significant changes in the number, scale, form, and location of advertising media. Before the implementation of regulations, building facades were characterised by a high density of signage and the presence of large-scale advertisements, often installed without regard for architectural composition. In many cases, advertising elements obscured architectural details and disrupted facade legibility.

Following the implementation of the landscape resolution, a substantial reduction in advertising intensity and improved integration of signage with architectural structure were observed. Advertising media became largely limited to ground-floor zones, while architectural divisions and decorative elements regained visual prominence.

The results of the comparative visual assessment are presented in Table 3. The analysis demonstrates changes in advertising density, architectural visibility, visual coherence, window transparency, and visual dominance before and after the implementation of the landscape resolution.

The comparative visual assessment demonstrates a consistent reduction in advertising density and a simultaneous increase in architectural visibility, visual

coherence, and facade readability across all analysed case studies. The most significant transformations were observed in buildings previously characterised by large-format advertising and fragmented visual communication systems (Cases 2 and 3). The results indicate a gradual shift from advertising-dominated facades towards compositions in which architecture regains visual dominance within the streetscape.

The observed changes also demonstrate a gradual reduction of visual clutter and an improvement in spatial order. At the same time, the degree of adaptation varies between buildings, reflecting the ongoing and uneven implementation of the landscape resolution.

6.5. Case Studies

Case 1 – Sienkiewicza 19

The facade was completely cleared of advertising elements (Fig. 11). Before the implementation of the landscape resolution, the ground floor was dominated by a continuous lightbox sign and window advertisements that obscured architectural details and disrupted the facade composition. Following the removal of these elements, the architectural divisions and decorative details became fully visible, restoring the architectural dominance of the building within the streetscape.

Table 3. Comparative visual assessment of facade transformations before and after implementation of the landscape resolution

Case Study	Advertising Density	Architectural Visibility	Visual Coherence	Ground-Floor Transparency	Visual Dominance
Case 1 – Before	2	2	2	2	1
Case 1 – After	5	5	5	5	5
Case 2 – Before	1	2	1	1	1
Case 2 – After	5	4	4	4	4
Case 3 – Before	1	1	1	2	1
Case 3 – After	4	4	4	4	4
Case 4 – Before	1	3	2	3	2
Case 4 – After	5	5	5	5	5
Case 5 – Before	2	2	1	2	1
Case 5 – After	4	5	5	5	5

Note: Assessment based on the five-point ordinal scale presented in Table 1. For all criteria, higher scores represent more favourable visual conditions. For Advertising Density, higher values indicate a lower concentration of advertising elements, whereas for the remaining criteria higher values indicate greater architectural visibility, visual coherence, window transparency, and the predominance of architecture over advertising.

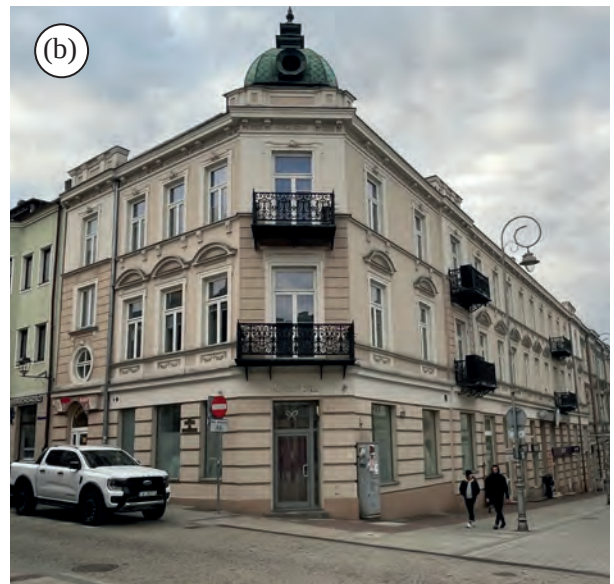


Fig. 11. Comparison of the facade at 19 Sienkiewicza Street before (a) [Source: J. Juruś] and after (b) the implementation of the landscape resolution [Source: J. Lech]

Case 2 – Sienkiewicza 36

The most significant change involved a substantial reduction and standardisation of advertising elements (Fig. 12). Prior to regulation, the facade was characterised by numerous signs, extensive window advertising, and inconsistent colour schemes, resulting in visual fragmentation. Following the implementation of the landscape resolution, advertising was reduced and visually unified, improving the transparency of the ground-floor zone and the readability of the facade.

Case 3 – Sienkiewicza 33

This case represents one of the most substantial transformations among the analysed buildings (Fig. 13). Before regulation, the facade was visually dominated by large-format vertical and horizontal advertisements that almost completely obscured the architectural composition. Following the implementation of the landscape resolution, large-format banners were removed, leaving only ground-floor signage. As a result, the building regained architectural readability and an appropriate visual hierarchy within the streetscape.

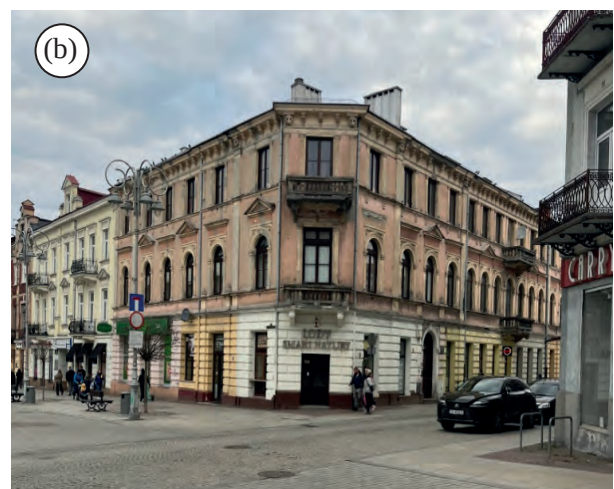


Fig. 12. Comparison of the facade at 36 Sienkiewicza Street before (a) [Source: J. Juruś] and after (b) the implementation of the landscape resolution [Source: J. Lech]



Fig. 13. Comparison of the facade at 33 Sienkiewicza Street before (a) [34] and after (b) the implementation of the landscape resolution [Source: J. Lech]

Case 4 – Sienkiewicza 11

This case illustrates the relationship between advertising reduction and facade revitalisation (Fig. 14). In addition to the removal of advertising elements, the building underwent renovation, including improvements to its colour scheme and architectural detailing. These interventions enhanced visual coherence and restored the representative character of the facade.

Case 5 – Sienkiewicza 17

This example illustrates the transition from visually aggressive commercial advertising to forms of visual communication more closely integrated with the architectural composition (Fig. 15). Before regulation, the facade contained banners, signage, and numerous window stickers arranged without compositional coherence. Following the removal of temporary advertising elements and the reorganisation of the remaining signage, both facade transparency and architectural visibility were substantially improved.



Fig. 14. Comparison of the facade at 11 Sienkiewicza Street before (a) [35] and after (b) the implementation of the landscape resolution [Source: J. Lech]



Fig. 15. Comparison of the facade at 17 Sienkiewicza Street before (a) [36] and after (b) the implementation of the landscape resolution [Source: J. Lech]

The presented case studies demonstrate that all analysed buildings experienced an improvement in the visual quality of their facades, although the magnitude of change varied. The greatest transformations were observed in buildings previously dominated by large-format advertisements and highly concentrated signage systems. Buildings with lower initial advertising intensity underwent more moderate changes; nevertheless, these also resulted in improved architectural readability and greater visual coherence.

6.6. Summary of Results

The comparative analysis demonstrates that the implementation of the landscape resolution in Kielce resulted in a clear improvement in the visual quality of the historic city centre. All analysed case studies showed a reduction in advertising intensity and an improvement in architectural readability, although the extent of change depended on the initial level of advertising saturation.

The greatest improvements were observed in buildings previously dominated by large-format advertisements and highly concentrated signage systems. In these cases, the removal of advertising restored the architectural composition, increased visual coherence, and improved the transparency of the ground-floor zone. Buildings with lower initial advertising intensity exhibited more moderate changes, yet they also showed a noticeable improvement in overall visual quality.

The findings indicate that the implementation of landscape regulations contributed to a redefinition of the visual hierarchy of the streetscape, shifting visual attention from commercial communication towards architectural composition. In several cases, compliance with the new regulations also acted as

a catalyst for broader renovation works and aesthetic improvements to building facades.

At the same time, the implementation process remains gradual and uneven, reflecting different levels of adaptation among property owners and commercial entities.

Overall, the findings confirm that landscape governance instruments can serve as effective tools for reducing visual pollution and improving urban landscape quality at both the street scale and the level of individual architectural objects.

7. CONCLUSIONS

Outdoor advertising constitutes an important component of the contemporary urban landscape, fulfilling informational, economic, and identity-related functions within public space. At the same time, the findings of this study demonstrate that excessive advertising intensity significantly affects the visual structure and perceptual quality of historic urban environments. The case of Kielce confirms that the rapid expansion of outdoor advertising following the post-socialist transformation, combined with the absence of effective regulatory instruments, resulted in substantial visual disorder, reduced architectural readability, and fragmentation of facade composition within the historic city centre.

The historical analysis further indicates that earlier forms of visual communication, particularly traditional signage and neon signs, were generally more closely integrated with architectural composition and urban identity than contemporary advertising systems. Their gradual replacement by low-cost, large-format, and visually dominant advertising media contributed to the deterioration of the historic streetscape and the weakening of the visual role of architecture.

The comparative visual assessment demonstrated that the implementation of the landscape resolution in Kielce in 2022 contributed to a noticeable reduction in advertising density, improved facade transparency, enhanced architectural visibility, and increased visual coherence within public space. The results indicate that landscape governance instruments can effectively restore the visual hierarchy of historic streets by shifting perceptual emphasis from commercial communication towards architectural composition.

These findings are consistent with previous research indicating that excessive outdoor advertising is one of the major contributors to visual pollution in urban environments and significantly reduces architectural legibility and spatial coherence [1, 10]. Similar conclusions have been reported in studies emphasising that limiting the scale and visual dominance of advertising improves the quality and readability of historic urban landscapes.

The results also support previous research highlighting the importance of landscape governance and regulatory planning instruments in protecting cultural heritage and improving the quality of public space [6, 14, 30]. While many existing studies focus primarily on large metropolitan areas, the present research demonstrates that comparable improvements can also be achieved in medium-sized post-socialist cities through locally adapted landscape regulations. This confirms that effective landscape governance is not limited to metropolitan contexts but can successfully contribute to the sustainable management of historic urban environments regardless of city size.

The present study extends previous research by combining a long-term historical perspective with a comparative visual assessment of facade transformations following the implementation of local landscape regulations. This integrated methodological approach provides empirical evidence of the relationship between landscape governance, architectural visibility, and visual quality, thereby contributing to the growing body of research on sustainable urban landscape management.

The study also demonstrates that effective landscape governance is not limited to large metropolitan areas. The case of Kielce shows that medium-sized cities can successfully implement regulatory instruments capable of producing measurable improvements in the visual quality of historic urban environments. These findings support the growing recognition of visual quality, architectural legibility, and spatial coherence as important components of sustainable urban development and human-centred public space design.

At the same time, the effectiveness of landscape governance depends not only on the adoption of legal regulations but also on their consistent enforcement, long-term spatial policy, and cooperation between local authorities, property owners, business operators, designers, and residents. The findings also confirm that advertising does not necessarily degrade urban space. When appropriately designed and integrated with its architectural and historical context, signage may contribute positively to place identity and the visual character of commercial streets.

This study contributes to the literature on urban landscape governance by integrating historical analysis, comparative visual assessment, and spatial interpretation of facade transformations within a medium-sized post-socialist city. The findings provide empirical evidence that local regulatory frameworks can significantly improve visual coherence and architectural visibility in historic urban environments.

The research is limited by its focus on a single case study and the use of qualitative and semi-quantitative visual assessment methods, which may involve a degree of interpretative subjectivity. Future research should therefore combine qualitative visual assessment with quantitative methods, including GIS-based visibility analysis, image segmentation techniques, eye-tracking studies, and comparative analyses involving multiple cities, to provide a broader understanding of the effectiveness of landscape governance instruments in reducing visual pollution and improving the quality of historic urban environments.

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CARBONATION OF CONCRETE: HISTORICAL DEVELOPMENT AND CHANGING INTERPRETATIONS

KARBONATYZACJA BETONU: ROZWÓJ HISTORYCZNY I ZMIENIAJĄCE SIĘ INTERPRETACJE

Maciej Lech

Kielce University of Technology, Poland

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Abstract

Carbonation of cement-based materials has been interpreted in different ways during the development of building materials and concrete technology. This paper presents a selective narrative review of the main milestones that changed the meaning of carbonation: from the useful hardening of lime binders, through the durability problem of reinforced concrete, to present discussions on blended and low-clinker binders, accelerated testing and CO₂ uptake. The review was based on historically important, methodologically relevant and currently influential literature. Particular attention was paid to the changing interpretation of carbonation in relation to binder composition, exposure conditions, reinforcement corrosion, testing methodology and the growing use of supplementary cementitious materials. The review shows that carbonation cannot be treated as a single, universal durability indicator. Its meaning depends on the type of binder, moisture conditions, pore structure, alkaline reserve, presence of reinforcement and the aim of assessment. The main conclusion is that concepts developed for ordinary Portland cement systems cannot be directly transferred to concretes rich in supplementary cementitious materials without additional interpretation and method-specific validation.

Streszczenie

Karbonatyzacja materiałów na bazie cementu była różnie interpretowana na kolejnych etapach rozwoju materiałów budowlanych i technologii betonu. W artykule przedstawiono selektywny przegląd narracyjny najważniejszych kamieni milowych, które zmieniały znaczenie karbonatyzacji: od korzystnego twardnienia spoiw wapiennych, przez problem trwałości żelbetu, aż po współczesne dyskusje dotyczące spoiw mieszanych i niskoklinkierowych, badań przyspieszonych oraz pochłaniania CO₂. Przegląd oparto na literaturze o znaczeniu historycznym, metodologicznym i współczesnym. Szczególną uwagę zwrócono na zmieniającą się interpretację karbonatyzacji w odniesieniu do składu spoiwa, warunków ekspozycji, korozji zbrojenia, metod badawczych oraz rosnącego stosowania dodatkowych materiałów cementowych. Przegląd pokazuje, że karbonatyzacja nie może być traktowana jako jeden uniwersalny wskaźnik trwałości. Jej znaczenie zależy od rodzaju spoiwa, warunków wilgotnościowych, struktury porów, rezerwy alkalicznej, obecności zbrojenia oraz celu oceny. Główny wniosek jest taki, że pojęć wypracowanych dla układów opartych na cemencie portlandzkim nie można bezpośrednio przenosić na betony bogate w dodatkowe materiały cementowe bez dodatkowej interpretacji i walidacji właściwej dla danej metody badawczej.

**REVITALISED MARKET SQUARES OF SMALL TOWNS
IN THE ŚWIĘTOKRZYSKIE REGION WITH FUTURE GENERATIONS IN MIND**
**ZREWITALIZOWANE RYNKI MAŁYCH MIAST W WOJEWÓDZTWIE ŚWIĘTOKRZYSKIM
Z MYŚLĄ O PRZYSZŁYCH POKOLENIACH**

Małgorzata Doroz-Turek
Kielce University of Technology, Poland

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Abstract

Revitalisation encompasses efforts aimed at resolving social, economic and spatial issues, particularly in smaller towns and cities, while also playing a vital role in preserving cultural heritage. The author presents this issue through the case studies of selected towns in the Świętokrzyskie region which date back to the Middle Ages, where local authorities employ revitalisation initiatives to restore them to their former glory and improve their usability. To achieve this, projects frequently leverage the towns' most valuable surviving assets – the historic urban layout, the medieval market square with its characteristic built environment, and other elements that shape local identity. This study aims to identify the evaluation criteria for the preserved historic fabric and the significance of heritage protection that guarantee the success of revitalisation. The research employs in situ investigations, comparative analysis, and an evaluation of completed revitalisation projects in selected towns and cities within the Świętokrzyskie Voivodeship, including Kielce, Sandomierz, Chęciny, Bodzentyn and Wiślica.

Streszczenie

Rewitalizacja obejmuje działania ukierunkowane na rozwiązywanie problemów społecznych, gospodarczych i przestrzennych – zwłaszcza w mniejszych miastach – a jednocześnie odgrywa istotną rolę w ochronie dziedzictwa kulturowego. Autor omawia to zagadnienie na przykładzie wybranych miast regionu świętokrzyskiego o średniowiecznym rodowodzie, w których władze lokalne podejmują inicjatywy rewitalizacyjne, by przywrócić im dawną świetność i poprawić ich funkcjonalność. W procesie tym często wykorzystuje się najcenniejsze zachowane zasoby: historyczny układ urbanistyczny, średniowieczny rynek z charakterystyczną zabudową oraz inne elementy kształtujące lokalną tożsamość. Celem niniejszego opracowania jest określenie kryteriów oceny zachowanej tkanki historycznej oraz znaczenia ochrony dziedzictwa dla powodzenia rewitalizacji. Badanie opiera się na wizjach lokalnych, analizie porównawczej oraz ocenie zrealizowanych projektów rewitalizacyjnych w wybranych miastach województwa świętokrzyskiego, w tym w Kielcach, Sandomierzu, Chęcinach, Bodzentynie i Wiślicy.

THE INFLUENCE OF DISPERSED REINFORCEMENT IN THE FORM OF BASALT FIBERS ON THE STIFFNESS MODULUS OF ASPHALT CONCRETE

WPŁYW ZBROJENIA ROZPROSZONEGO W POSTACI WŁÓKIEŃ BAZALTOWYCH NA MODUŁ SZTYWNOŚCI BETONU ASFALTOWEGO

Wiktoria Ściga, Przemysław Buczyński, Grzegorz Mazurek
Kielce University of Technology, Poland

Hümeýra Bolkar Tosun
Aksaray Üniversitesi, Turkey

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Abstract

This article analyzes the effect of dispersed reinforcement in the form of basalt fibers on the stiffness modulus of asphalt concrete. The research program included an AC 16W mineral-asphalt mixture intended for a binder course reinforced with 30 mm long basalt fibers at 0.5% and 1.5% by weight, as well as options with adjusted asphalt content. Laboratory tests showed that the addition of basalt fibers significantly increases the stiffness of the mixture across the entire tested temperature range from 5°C to 40°C, achieving in the 1.5% variant (AC_1.5%) S_m modulus values nearly twice as high as those of the reference mineral-asphalt mixture (R). It was also noted that changing the binder content led to a significant reduction in stiffness at the analyzed temperatures, which may protect the pavement against low-temperature cracking. Despite differences in composition, all tested mixtures maintained high water resistance at 91–98%, confirming that proper dosing of basalt fibers without excess binder yields the most durable structure resistant to permanent deformation.

Streszczenie

W niniejszym artykule przeanalizowano wpływ zbrojenia rozproszonego w postaci włókien bazaltowych na moduł sztywności betonu asfaltowego. Program badań obejmował mieszankę mineralno-asfaltową typu AC 16W, przeznaczoną na warstwę wiążącą, zbrojoną włóknami bazaltowymi o długości 30 mm w ilości 0,5% i 1,5% masy, a także warianty z zmodyfikowaną zawartością asfaltu. Badania laboratoryjne wykazały, że dodatek włókien bazaltowych znacząco zwiększa sztywność mieszanki w całym badanym zakresie temperatur (od 5°C do 40°C); w przypadku wariantu z 1,5% dodatkiem włókien (AC_1,5%) uzyskano wartości modułu sztywności (S_m) niemal dwukrotnie wyższe niż dla referencyjnej mieszanki mineralno-asfaltowej (R). Odnotowano również, że zmiana zawartości lepiszcza prowadziła do istotnego obniżenia sztywności w analizowanych temperaturach, co może chronić nawierzchnię przed spękaniami niskotemperaturowymi. Mimo różnic w składzie, wszystkie badane mieszanki zachowały wysoką odporność na działanie wody (na poziomie 91–98%), co potwierdza, że właściwe dozowanie włókien bazaltowych – bez nadmiaru lepiszcza – pozwala uzyskać najbardziej trwałą strukturę, odporną na odkształcenia trwałe.

**TRANSFORMATION OF THE ADVERTISING LANDSCAPE AND LANDSCAPE GOVERNANCE
IN A HISTORIC CITY CENTRE: THE CASE OF KIELCE (POLAND)**

**PRZEKSZTAŁCENIA KRAJOBRAZU REKLAMOWEGO I ZARZĄDZANIA KRAJOBRAZEM
W HISTORYCZNYM CENTRUM MIASTA: PRZYPADEK KIELC (POLSKA)**

Jagoda Juruś, Julia Lech
Kielce University of Technology, Poland

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Abstract

The rapid expansion of outdoor advertising in post-socialist cities has transformed the visual structure of historic urban landscapes, contributing to visual pollution. This study investigates the transformation of the advertising landscape in the historic city centre of Kielce (Poland) and evaluates the effectiveness of landscape governance in improving visual quality and spatial order. The research combines a literature review, historical analysis, planning document analysis, field observations, and a semi-quantitative comparative visual assessment of selected building facades. The results indicate that historical forms of advertising were generally better integrated with architectural composition, whereas post-1989 advertising contributed to visual fragmentation. The implementation of the 2022 landscape resolution reduced advertising density, improved architectural visibility, enhanced visual coherence, and increased the transparency of ground-floor facades. The findings demonstrate that local landscape governance can effectively reduce visual pollution and support the sustainable management of historic urban environments.

Streszczenie

Gwałtowny rozwój reklamy zewnętrznej w miastach post-socjalistycznych przekształcił wizualną strukturę historycznych krajobrazów miejskich, przyczyniając się do powstania zanieczyszczenia wizualnego. Niniejsze badanie analizuje przemiany krajobrazu reklamowego w historycznym centrum Kielc (Polska) oraz ocenia skuteczność działań w zakresie zarządzania krajobrazem pod kątem poprawy jakości wizualnej i ładu przestrzennego. Metodologia badań obejmuje przegląd literatury, analizę historyczną, analizę dokumentów planistycznych, obserwacje terenowe oraz półilościową, porównawczą ocenę wizualną wybranych elewacji budynków. Wyniki wskazują, że historyczne formy reklamy były zazwyczaj lepiej wkomponowane w kompozycję architektoniczną, podczas gdy reklamy powstałe po 1989 roku przyczyniły się do fragmentacji wizualnej przestrzeni. Wdrożenie uchwały krajobrazowej z 2022 roku doprowadziło do zmniejszenia zagęszczenia reklam, poprawy widoczności architektury, zwiększenia spójności wizualnej oraz poprawy przejrzystości elewacji na poziomie parteru. Uzyskane wyniki dowodzą, że lokalne zarządzanie krajobrazem może skutecznie ograniczać zanieczyszczenie wizualne i wspierać zrównoważone gospodarowanie historycznymi przestrzeniami miejskimi.