

DETERIORATION MECHANISMS OF NEW JERSEY BARRIERS ON HIGHWAY CORRIDOR VC SECTION ZENICA-SARAJEVO

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ABSTRACT:

This research examines the deterioration processes affecting New Jersey concrete barriers along the Zenica-Sarajevo corridor, a vital transportation artery in Bosnia and Herzegovina. Employing a comprehensive approach that integrates visual inspections, drone-based imagery, and geospatial analysis, the study pinpoints several key factors driving barrier degradation. These include mechanical impacts, chemical corrosion, environmental stressors, and issues stemming from construction practices. The most prevalent forms of damage observed were cracking, spalling, and reinforcement corrosion, particularly pronounced in areas with heavy traffic and insufficient drainage. Environmental factors, namely freeze-thaw cycles and chloride ingress from de-icing salts were found to exacerbate deterioration, with damage patterns varying significantly by location due to differences in local climate, traffic intensity, and material quality. The findings underscore the necessity of proactive maintenance regimes, such as routine post-winter inspections and targeted repairs, alongside the implementation of design improvements. Recommendations include adopting corrosion-resistant reinforcements, optimizing drainage, and considering alternative barrier profiles like the F-shape to enhance durability. While the study offers valuable insights, it acknowledges limitations, such as its reliance on surface-level observations and the restriction to a single season of monitoring. Future research should incorporate long-term data collection and in-depth material testing. In summary, the study highlights the importance of tailoring infrastructure management strategies to specific regional conditions in order to maximize the longevity and safety of concrete barriers.

KEYWORDS:

New Jersey barriers, concrete deterioration, freeze-thaw cycles, chloride corrosion, highway infrastructure, Corridor Vc, maintenance strategies.

1 INTRODUCTION

New Jersey barriers typically operate as understated sentinels of road safety—largely unnoticed until an incident draws attention to their presence. Most damage arises from direct impacts, though gradual, uneven wear can also occur and is often only evident upon close inspection. These barriers are engineered to absorb considerable force and are designed for relatively straightforward and cost-effective replacement.

Yet, the segment of Corridor Vc between Zenica and Sarajevo presents a notable challenge to these assumptions. This roadway serves not merely as a transport link, but as a critical artery for both passenger and freight movement. The region's severe climate—characterized by harsh winters and intense summer heat—subjects concrete structures to stresses that frequently surpass their intended capacities.

While deterioration phenomena such as corrosion, carbonation, abrasion, and impact are generally well-documented, their combined effects under specific local conditions remain insufficiently understood. Corridor Vc, in particular, offers a distinctive setting where high traffic volumes, climatic extremes, and varied construction standards converge, resulting in a complex and evolving pattern of structural stress.

This paper aims to analyze these stress factors in depth, investigating the mechanisms behind damage to New Jersey barriers along this corridor, from early-stage cracking to joint separation. By focusing on the unique, site-specific challenges rather than relying on generalizations, the objective is to enhance strategies for early detection and intervention, reducing the risk of severe deterioration.

1.1 TYPES AND FUNCTIONS OF NEW JERSEY BARRIERS

New Jersey-shaped concrete median barriers were developed in the United States in the mid-20th century and have since been widely adopted because their simple geometry provides effective vehicle containment and redirection; their design and performance have been extensively evaluated in subsequent crash and deployment studies [1]. The main concept of the barrier design is extraordinarily simple: keep vehicles away from oncoming traffic or off the road itself. And this simplicity might be the very basis of its long-lasting success.

Various types of these barriers exist. The most common and well-known types are the precast concrete barriers that are heavy, solid, and suitable for permanent installation [2]. For temporary or short-term use, plastic water-filled barriers are preferred because they can be moved around quite easily and are very visible [3]. Furthermore, everyone should know that the F-shape, however, varies the slope to lessen lift during impact and thereby augment vehicle stability during collisions [4].

The New Jersey concrete safety barriers installed along the Zenica-Sarajevo section of Corridor Vc were designed as continuous reinforced-concrete elements in accordance with the technical specifications of JP Autoceste FBiH and the European road-safety barrier standard EN 1317 [5].

The barrier profile follows the typical New Jersey geometry, with an overall height of approximately 0,80 m, base width of about 0,55 m, and crown width tapering to roughly

0,18 m, ensuring the deflection and redirection performance required to minimize vehicle impact forces [5].

The structure is composed of C30/37 concrete reinforced with B500B ribbed steel. Longitudinal reinforcement bars extend continuously and are tied with transverse stirrups at roughly 20 cm spacing to provide bending resistance and impact durability. Construction was carried out in 2009 by Euro-Asfalt d.o.o. Sarajevo, using a continuous slip-form casting technique, which allowed homogeneous concrete placement and efficient production of long, joint-free segments. The exposed surface was mechanically finished and treated with a hydrophobic seal to reduce water and de-icing-salt penetration, followed by light grinding to achieve the specified texture and slip resistance.

Apart from stopping vehicles from crossing over, New Jersey barriers serve additional safety purposes. They assist in containing and redirecting vehicles during collisions [6], control traffic in construction areas [7], and offer safety to pedestrians and workers on the road. These barriers, when properly installed and maintained, provide a dependable safety measure in many transportation situations.

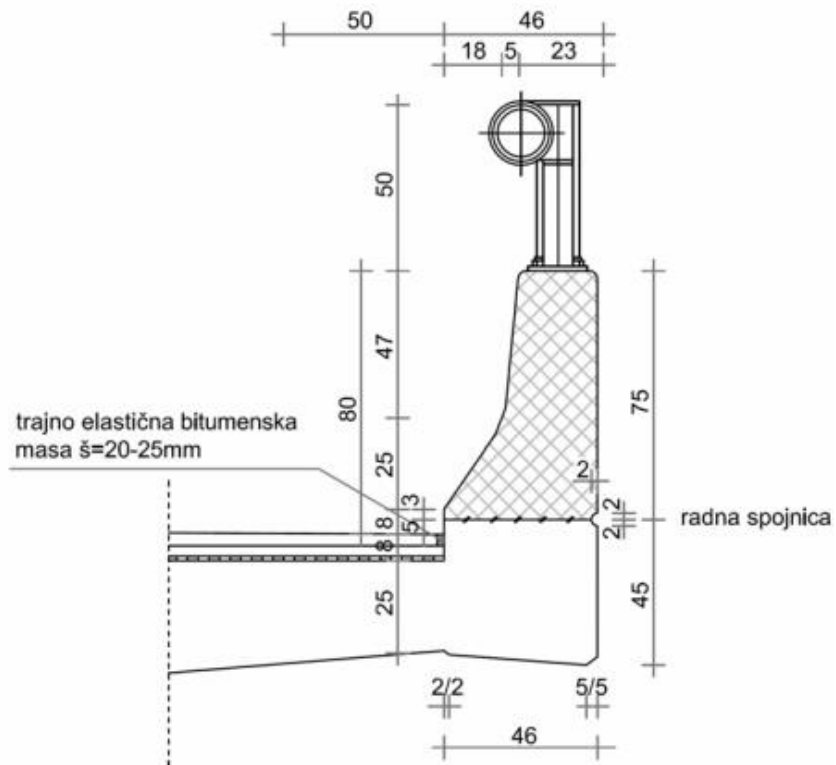


Figure 21 External monolithic New Jersey barrier - height 80 (110 cm) [5]

1.2 COMMON DETERIORATION MECHANISMS

Concrete might seem like an unchanging, durable material, but it's actually in a constant state of flux, interacting with its environment in ways that gradually undermine its integrity.

This is particularly evident in New Jersey barriers, which consistently show up in research as examples of these recurring failure mechanisms.

Freeze-thaw cycles are a major culprit. In climates such as Bosnia and Herzegovina, moisture infiltrates small cracks in the concrete. When cold weather hits, that water freezes and expands, developing internal stresses that slowly fracture the surface [9]. While damage might seem minor at first, it accumulates over time and becomes much more apparent after several seasons.

Chemical deterioration is another significant factor. Chloride ions, usually from road salts, can work their way into the concrete, eventually reaching any embedded steel reinforcement. Once that steel starts to corrode, the rust expands and puts pressure on the concrete from the inside, leading to more cracking and structural compromise [10] [11]. Sulfate attacks, though a bit less common, also pose a threat especially if the local soil or groundwater contains problematic chemistry [9].

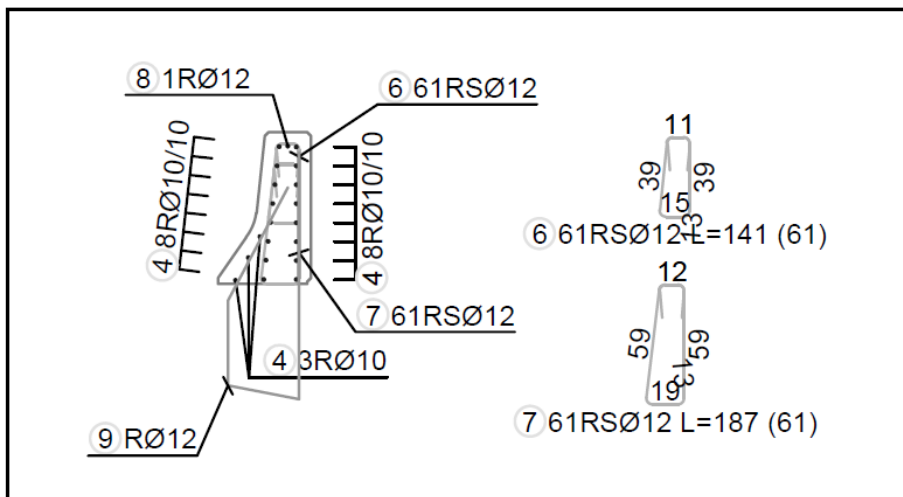


Figure 22 Reinforcement plan, concrete safety barrier [8]

In summary, concrete's apparent solidity masks a slow but steady process of deterioration, driven by environmental and chemical factors that researchers have documented extensively.

Mechanical wear plays a significant role in the deterioration of concrete barriers. Even minor impacts can lead to ongoing abrasion, while tire friction, debris strikes, and routine surface contact gradually erode the concrete structure [12] [13]. Notably, these processes seldom occur independently. Rather, it is the interplay of physical, chemical, and environmental factors that collectively contribute to the visible damage and ongoing structural decline observed in these barriers.

1.3 ENVIRONMENTAL AND TRAFFIC INFLUENCES

Concrete isn't simply a static material it actively interacts with its environment. For road barriers, this means continuous exposure to environmental fluctuations, chemical agents, and traffic loads, all of which influence patterns and severity of deterioration.

The Zenica-Sarajevo stretch serves as a representative case study. The region experiences severe winters, where repeated freeze-thaw cycles accelerate internal cracking and surface scaling [9]. Additionally, the application of de-icing salts exacerbates deterioration by allowing chemical ingress, particularly chlorides, which are notorious for inducing corrosion in reinforcement steel [14].

Traffic intensity further complicates the situation. Heavy freight vehicles, and especially the repetitive loading from trucks, generate vibrations and microfractures within the barrier structures. Over time, these cumulative stresses manifest as visible damage: cracking, spalling, or even displacement of individual barrier sections [15] [16].

The distribution of damage is far from uniform along the corridor. Barriers located near curves or highway merge zones experience unique mechanical stresses due to frequent braking and directional changes, resulting in localized wear [15]. This site-specific degradation illustrates the limitations of generic maintenance protocols and underscores the necessity for tailored strategies that address the distinct conditions present at each location.

1.4 PREVIOUS RESEARCH ON SIMILAR CORRIDORS

Research specifically directed at the Zenica - Sarajevo segment remains somewhat scarce, but studies from other major transport corridors offer a useful basis for understanding expected deterioration mechanisms. These investigations consistently demonstrate that concrete structures subjected to intense freight traffic and challenging environmental conditions tend to deteriorate at an accelerated rate. Notably, regardless of whether the primary subject is bridges or barriers, the observed damage patterns are strikingly similar. For example, a 2009 study by [17] on reinforced concrete bridges showed that both overloading and corrosion substantially reduce long-term stiffness and durability. Likewise, [18] examined road barriers exposed to repeated vehicular impacts and identified recurrent issues such as cracking, spalling, and localized material loss. These findings highlight how even moderate but repeated mechanical stresses can accumulate, ultimately leading to significant degradation over time.

More regionally relevant, the [19] has demonstrated the impact of proactive maintenance strategies. Their approach goes beyond routine inspections, incorporating regular and targeted interventions such as surface sealing, crack repair, and timely remediation of minor defects. Such practices have proven to markedly improve safety and reduce failure rates, particularly in climates where moisture and de-icing salts present additional challenges.

Material innovation is also becoming increasingly important. The adoption of high-performance concretes, impact-absorbing barrier designs, and corrosion-resistant reinforcements is on the rise [20] [16]. Furthermore, ongoing research is investigating modifications to barrier profiles to better manage dynamic loads [4].

Taken together, these studies underscore a key point: deterioration processes exhibit identifiable patterns that, when closely monitored and effectively managed within local contexts, can be anticipated and mitigated. The present paper aims to apply these broader findings to the specific circumstances along Corridor Vc, with the objective of improving the durability and overall performance of New Jersey barriers in this critical section.

2 BACKGROUND AND METHODS

The investigation of deterioration mechanisms affecting New Jersey concrete barriers along the Zenica–Sarajevo segment of Corridor Vc was based on direct field documentation combined with post-construction information supplied by the original contractor. The goal was to identify dominant forms of structural distress and evaluate the effectiveness of past repair interventions under the corridor's specific operating conditions.

Field data were obtained through a systematic photographic survey carried out along the entire motorway section. Barrier segments were inspected visually, and every location showing visible signs of distress, such as cracking, spalling, joint separation, surface abrasion, or reinforcement exposure was photographed using a high-resolution digital camera. Each image was recorded with date, chainage, and GPS coordinates to ensure accurate spatial reference and to allow subsequent comparison of damage intensity across different subsections of the corridor. This procedure follows the principles of condition assessment described in similar highway infrastructure studies [21] [22].

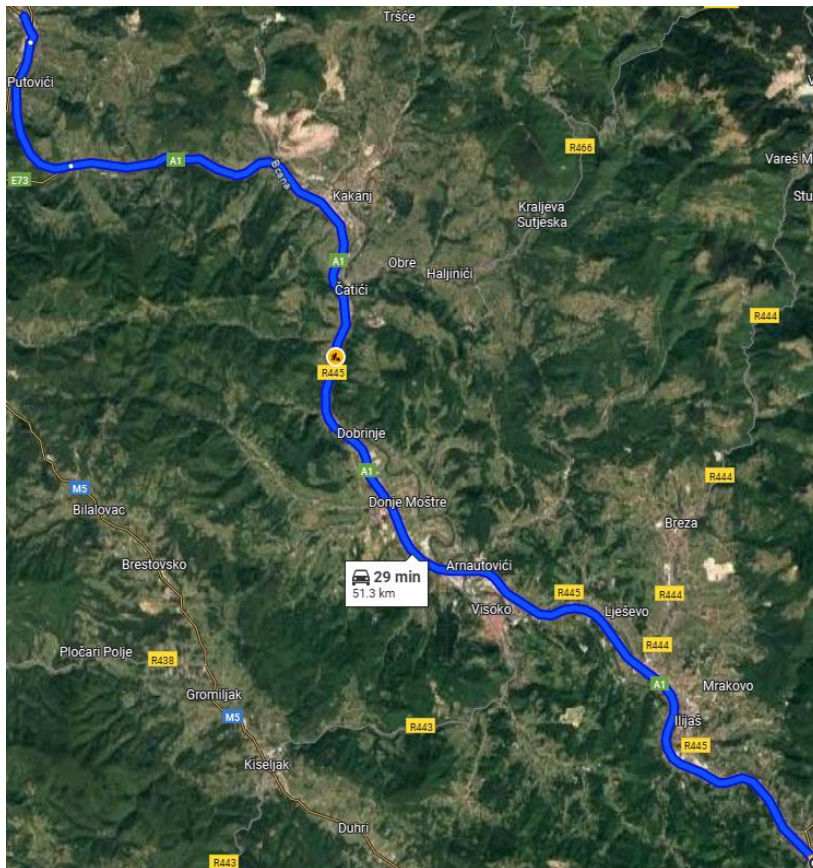


Figure 23 Analyzed road segment

In addition to surface documentation, qualitative observations of surrounding conditions were noted, including drainage quality, proximity to expansion joints, and the presence of vegetation or water accumulation. These contextual records facilitated interpretation of possible causal factors such as freeze-thaw action or poor surface runoff.

To complement the field survey, the construction company Euro-Asfalt d.o.o. Sarajevo responsible for the original installation in 2009, provided relevant project documentation. These records included material specifications (C30/37 concrete and B500B reinforcement), details of the slip-form casting technique, and maintenance logs describing previous repairs and the methods employed for crack sealing and partial replacement of barrier segments. Information on the frequency and type of remedial actions enabled evaluation of how initial construction quality and subsequent maintenance influenced current deterioration patterns.

Collected photographic and documentary data were organized into a georeferenced database. Each barrier segment was classified according to the observed damage type and rated by severity using a three-level index adapted from the American Concrete Institute's concrete surface evaluation guidelines [23]. Descriptive statistics were then applied to determine the prevalence of specific deterioration mechanisms, while spatial grouping of defects was examined to identify recurring correlations with drainage features, traffic intensity, or micro-climatic exposure.

This combined methodology, integrating field photography, qualitative site observations, and contractor-provided maintenance records provided a robust empirical basis for characterizing the deterioration of New Jersey barriers on Corridor Vc. By grounding the analysis in directly collected evidence and verified construction data, the study ensures that conclusions regarding the mechanisms of damage and the efficacy of past repairs accurately reflect the conditions encountered along this critical motorway segment.

3 RESULTS AND DISCUSSION

3.1 IDENTIFIED DETERIORATION MECHANISMS

3.1.1 Mechanical Damage

Physical impacts remain the most apparent cause of damage to New Jersey barriers. Vehicles especially heavy trucks rarely stay perfectly within their lanes; even minor contact can leave significant wear over time. The cumulative effect of repeated bumps, scrapes, and occasional crashes leads to visible cracking, surface chipping, and, in more severe cases, displacement of entire barrier sections [24].



Figure 24 Diagonal cracking and edge separation caused by repeated vehicle contact and surface fatigue

In addition to direct collisions, abrasion plays a notable role in gradual barrier deterioration. Tires and loose debris consistently wear down the concrete, particularly along the edges. This ongoing erosion gradually strips away the protective layer, contributing to the overall degradation of the barrier [12]. Areas such as curves and merging lanes are especially susceptible to edge erosion, which, although not immediately critical, accumulates over time.

Field observations and photographs reveal diagonal cracking and surface fatigue clear indicators of stress from repeated vehicular contact. Furthermore, slight separations at the joints were documented, suggesting that some of the damage extends below the surface and may indicate deeper structural movement.

3.1.1 Chemical deterioration

Chemical deterioration of concrete barriers often goes unnoticed, yet it's just as destructive as more obvious forms of damage. The application of de-icing salts in winter introduces chloride ions to the concrete. These ions gradually infiltrate the structure through existing pores and microcracks, eventually reaching the embedded steel reinforcement.



Figure 25 Cracking and minor joint separation suggest structural stress and possible construction-related defects

Once chlorides meet the steel, corrosion initiates. This process leads to the steel expanding, which generates internal stresses. As a result, the surrounding concrete begins to crack and fracture. Field inspections have revealed surface staining and rust marks both classic indicators of ongoing corrosion. In several cases, spalling had advanced to the point where corroded rebar was exposed, clearly demonstrating the extent of chemical damage in those areas.

Carbonation progresses subtly it's not immediately apparent but unfolds gradually over time. Essentially, carbon dioxide from the air penetrates the concrete and reacts with the cement, steadily lowering the material's pH. As this happens, the environment surrounding the steel reinforcement becomes much less protective, leaving the steel susceptible to corrosion.

While carbonation and chloride-induced corrosion are technically separate processes, in real-world scenarios, they frequently occur together. This overlap significantly increases the risk of steel corrosion and speeds up the deterioration of the protective concrete barrier [25].

3.1.1 Environmental effects

Environmental stressors cause considerable deterioration in concrete barriers, especially by way of cracking and surface scaling. Of particular concern is the freeze-thaw cycle prevalent in this area. Water infiltrates microcracks, then expands when frozen, producing internal pressures that gradually fracture the concrete [26].



Figure 26 Evidence of corrosion-induced staining embedded steel reinforcement, indicating chloride ingress and carbonation

This phenomenon is especially pronounced at higher elevations, where lingering snow and ice increase exposure to freeze-thaw action. Once the surface shows initial signs of deterioration, it becomes more vulnerable to additional damage from moisture ingress, salt, and physical impacts.

Furthermore, ultraviolet (UV) radiation, while operating more slowly, also contributes to degradation by breaking down surface coatings and causing drying and shrinkage over time. Field observations have noted minor surface cracking and shrinkage in several locations, consistent with long-term UV exposure [27].

3.1.2 Construction defects

Not every instance of deterioration stem from external sources; some issues are embedded right from the construction phase. Insufficient compaction, poor curing, and careless placement of reinforcement bars can undermine the structural integrity of concrete barriers before they're even put into service [27].

During recent inspections, a higher-than-expected number of construction-related deficiencies came to light. Several segments displayed misaligned joints, which introduce localized stress concentrations and accelerate subsequent damage. In addition, certain areas revealed concrete that was unusually porous, suggesting that the mix quality was subpar. Although these flaws might not trigger immediate failure, they undeniably reduce the barriers' resistance to both mechanical impacts and chemical deterioration.

While these mechanisms of deterioration aren't unique to Corridor Vc, the particular mix of construction flaws, combined with the corridor's traffic patterns and climate, offers valuable insight into long-term degradation trends specific to the region.

3.2 FIELD SURVEY RESULTS

3.2.1 Condition assessments

The field survey conducted along the Zenica–Sarajevo section of Corridor Vc revealed considerable heterogeneity in the condition of the concrete barriers. Cracking was the most pervasive form of deterioration observed, manifesting both longitudinally and transversely. In several locations, these cracks were accompanied by spalling, and in areas with more advanced deterioration, the steel reinforcement was visibly exposed evidence of corrosion likely accelerated by chloride ingress.

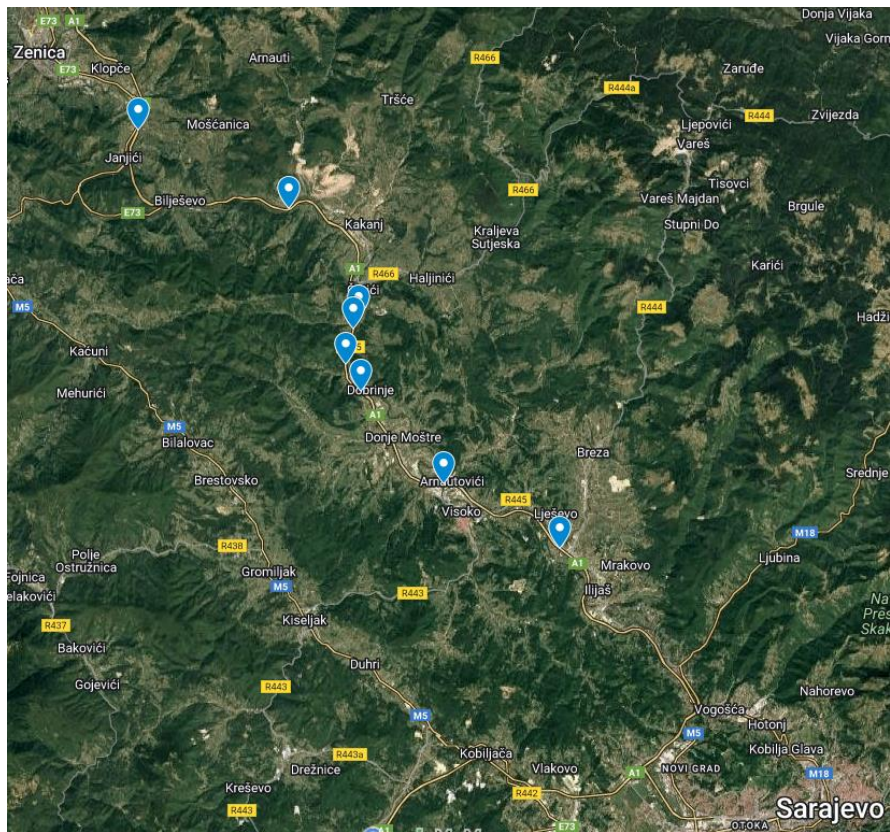


Figure 27 Locations of observed damages

Particularly at intersections with drainage pathways or in low-lying sections, efflorescence was frequently noted. The presence of white streaks and salt deposits on the concrete surface is indicative of ongoing moisture infiltration and freeze-thaw cycling, phenomena often associated with prolonged water retention. These are not merely aesthetic concerns; they suggest a risk of progressive, long-term structural compromise.



Figure 28 General view of deterioration New Jersey barrier showing large areas of spalling, surface scaling and reinforcement exposure near high-traffic segment



Figure 29 Vertical and transverse cracks along the lower section of the barrier, indicating structural fatigue and environmental wear

Subtler indicators of deterioration included surface abrasion resulting from vehicular traffic, debris, and age-related wear. This typically presented as erosion and loss of surface texture, notably along the edges of the barriers. In areas characterized by persistent dampness and limited sunlight, biological growth such as moss and algae were present. While such growth does not directly attack the concrete, it serves to retain moisture, thereby exacerbating freeze-thaw damage.

Alignment irregularities were also observed. Certain barrier segments had shifted, most likely due to vehicular impact, resulting in discontinuities that threaten both the structural integrity and the intended safety function of the barriers.

Photographic documentation further illustrated the variability in deterioration. In some instances, a barrier segment was nearly pristine and free from visible distress, while an adjacent segment displayed pronounced cracking, spalling, and discoloration. This stark contrast highlights the significant influence of micro-environmental factors such as slope and sun exposure on the rate and severity of barrier deterioration along the corridor.

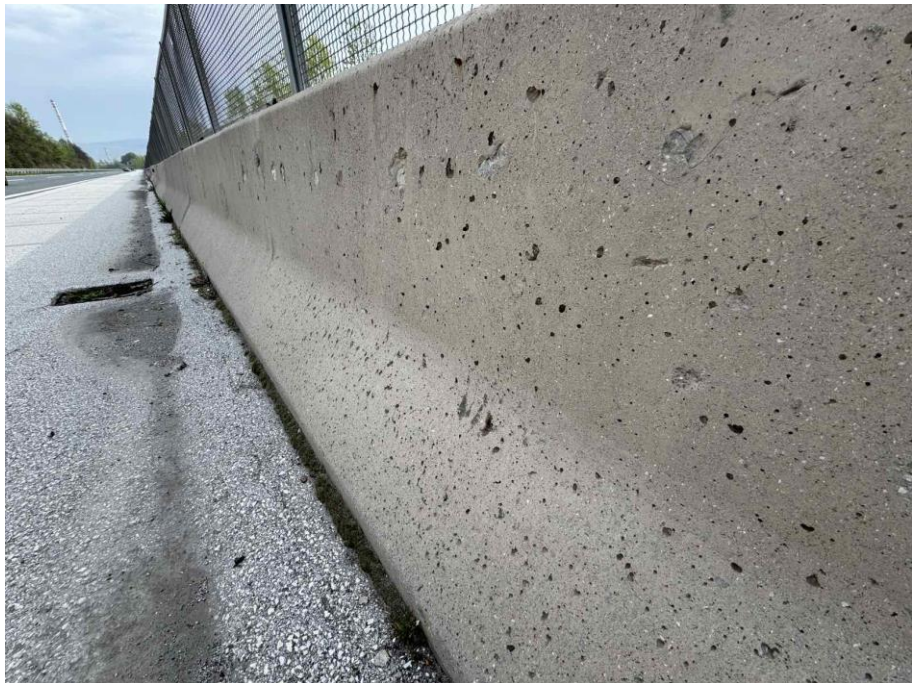


Figure 30 Segment of a minimally deteriorated New Jersey barrier for comparison with damaged sections

3.2.2 Damage types and spatial distribution

An analysis of the data collected from Corridor Vc highlights several distinct patterns of deterioration. Expansion joints routinely emerged as points of vulnerability, with cracking and spalling commonly observed in their vicinity particularly in regions exposed to severe winter conditions. This pattern aligns with the well-documented effects of moisture infiltration and repeated freeze-thaw cycles, which incrementally exacerbate existing cracks over time.

Cracking and delamination along the upper edges of barriers represented another prevalent issue. These defects were most often associated with sections subjected to prolonged sunlight exposure. The combination of thermal expansion and surface drying appears to induce uneven stress distribution in these areas, facilitating the development and propagation of microcracks that ultimately culminate in visible structural damage.

At the base of certain barriers especially in inadequately drained zones there was clear evidence of erosion and intrusion by vegetation. Water runoff tends to accumulate in these locations, elevating moisture levels and promoting local instability. Once vegetation establishes itself within cracks or joints, root growth exerts additional mechanical pressure, thereby accelerating deterioration.

Notably, damage was not uniformly distributed along the corridor. Instead, deterioration was concentrated in specific locations characterized by sharp curves, high traffic volumes, and inconsistent drainage. This non-uniform distribution reinforces findings from previous studies, which demonstrate that deterioration is influenced more significantly by localized site conditions than simply by the passage of time.

3.2.3 Correlation of damage with traffic, elevation and drainage issues

Overlaying visual condition data with location-specific variables reveals a clear relationship: areas experiencing higher traffic volumes, particularly near urban centers such as Sarajevo, exhibit more severe surface fatigue, including abrasion and cracking. This outcome aligns with established expectations mechanical stress from increased truck traffic accelerates barrier deterioration.

Yet, traffic density alone does not account for all observed patterns of damage. There are notable instances where sites with relatively low traffic still demonstrate significant degradation. Closer examination attributes this to inadequate drainage; specifically, persistent moisture exposure leads to water accumulation, especially near slopes or drainage runoff zones. When this moisture freezes overnight, it amplifies deterioration through repeated freeze-thaw cycles, even in the absence of heavy vehicle loads.

Additionally, barriers situated at higher elevations appear disproportionately affected. Survey data indicate that these segments, while not necessarily subject to more traffic, are exposed to harsher environmental conditions namely, prolonged snow and ice retention. This environment accelerates freeze-thaw driven cracking and surface scaling.

In conclusion, the degradation of roadside barriers is the result of a complex interplay between location, traffic loading, and environmental exposure. The patterns identified here are consistent with international research [28], yet they also emphasize the significant influence of site-specific conditions on the deterioration process.

3.3 INTERPRETATION AND BROADER DISCUSSION

3.3.1 Link findings to international research

The patterns of deterioration observed along the Zenica–Sarajevo corridor (Corridor Vc) reveal both globally recognized mechanisms and notable regional distinctions. The degradation of New Jersey-type concrete barriers in this section is multifactorial, arising from cumulative stresses such as repeated vehicular impacts, environmental extremes (notably freeze-thaw cycles), the chemical effects of de-icing salts, and initial construction shortcomings.

Cracking and spalling are most pronounced where steel reinforcement is exposed, indicating that chloride-induced corrosion is a primary driver of structural decline. The presence of efflorescence and staining points to ongoing water infiltration, especially in areas with inadequate drainage infrastructure. These environmental pressures, compounded by insufficient moisture management, accelerate barrier degradation over time. Mechanical damage, particularly in zones of high traffic volume and on curved road segments, further exacerbates the problem, as repeated impacts and vibrations concentrate stress on these structures. Additional evidence such as joint misalignment, surface abrasion, and localized displacements corroborates the relationship between mechanical stress and observed deterioration.

In comparison with international research, the deterioration mechanisms along Corridor Vc largely parallel those documented in other cold, mountainous regions characterized by similar traffic and maintenance conditions. The detrimental effects of chloride ingress, freeze-thaw cycling, and inadequate drainage are widely acknowledged. Furthermore, early-stage construction deficiencies, such as substandard concrete quality or poorly executed joints consistently undermine the long-term durability of highway barriers, as reported in studies of aging infrastructure worldwide.



Figure 31 Widespread delamination and material separation likely due to inadequate surface treatment and poor curing

Nonetheless, the local context of Corridor Vc introduces distinct variations. Certain segments deteriorate more rapidly due to unique combinations of elevation, orientation, sun exposure, and drainage patterns. These microclimatic and topographical factors contribute to highly uneven rates of deterioration along the route. As a result, a uniform

maintenance approach is unlikely to be effective. Comprehensive understanding of how common degradation processes interact with Corridor Vc's specific conditions is essential for developing targeted interventions and predictive maintenance strategies tailored to this corridor's requirements.

3.3.2 Implications for maintenance and design

The principal implications of the study are that proactive maintenance is essential. Severe damage typically originates from minor issues such as early cracks, slight misalignments, or persistent moisture. If these issues are spotted during regular inspections, they're much easier to manage.

Drainage improvement is also a major priority. Accumulated water speeds up deterioration, so it's important to focus on effective slope management, keep runoff channels clear, and, when necessary, reconsider the elevation and overall layout of sections that seem especially vulnerable.

From a design perspective, the research makes it clear that durable materials matter a lot. Using high-performance concrete and corrosion-resistant reinforcements can add years to a structure's service life. Barrier profiles such as the F-shape have also shown to reduce displacement from vehicle impacts, which improves overall stability [16] [4].

Finally, construction quality shouldn't be overlooked. Improved curing techniques, precise control of concrete mixes, and careful installation of joints help eliminate early-stage weaknesses. Attention to these details during construction can prevent significant long-term deterioration.

The objective is not perfection but structural resilience. Structures will inevitably endure both environmental and mechanical pressures. Still, by employing more intelligent design strategies, selecting advanced materials, and ensuring maintenance happens when it should, we can significantly boost both the durability and safety of these barriers. Effective maintenance relies on practical, well-planned interventions rather than on the pursuit of flawless outcomes.

3.3.3 Study limitations

This study, like most field-based research, encountered several notable limitations practical and methodological alike. While these do not negate the core findings, they do warrant a degree of caution in drawing broad conclusions.

To begin with, the research was confined solely to the Zenica - Sarajevo segment of Corridor Vc. Consequently, the results are geographically limited. Observed patterns may hint at wider trends, but should not be interpreted as representative of the entire corridor, let alone other regions.

Furthermore, the assessment methodology relied exclusively on surface-level visual inspections. Advanced diagnostic tools such as ultrasonic testing or core sampling were not utilized. As a result, subsurface issues such as early-stage corrosion invisible to the naked eye may have gone undetected. The evaluation of barrier integrity, therefore, was based solely on external appearance.

The timing of the inspections also posed a limitation. Conducted in autumn, prior to the onset of severe winter conditions, the inspections offered only a limited temporal snapshot. Subsequent damage from freeze-thaw cycles or salt exposure may have

occurred after the study period. A more comprehensive understanding would require longitudinal or multi-seasonal assessments.

Interpretation of findings was occasionally challenging. Even with standardized protocols in place, distinguishing between damage caused by mechanical impacts versus environmental factors (such as freeze-thaw cycles) sometimes required subjective judgment.

Finally, the study did not incorporate real-time traffic load monitoring or chemical analysis of materials both of which could provide deeper insights into degradation mechanisms and causality. Future research incorporating these elements would likely yield a more robust understanding.

4 CONCLUSION

The New Jersey barriers installed along Corridor Vc serve a crucial function in safeguarding road users, yet they are consistently subjected to a range of mechanical, environmental, and chemical stressors. This study analyzed the deterioration of these barriers under region-specific conditions, aiming to identify both the primary mechanisms of damage and viable strategies for mitigation.

The investigation, though limited to a particular segment of the corridor, highlighted several recurring patterns. Field observations indicated that cycles of freezing and thawing, chloride penetration, and substantial traffic loads when coupled with construction deficiencies substantially expedite the rate of deterioration. Common issues such as inadequate drainage, high concrete porosity, and poorly aligned joints were repeatedly noted, underscoring persistent flaws in both construction practices and ongoing maintenance.

The findings align with established research in other regions, they also emphasize the necessity of calibrating standard interventions to address unique local factors such as climate variations, soil composition, and traffic intensity. The interventions suggested by the analysis routine post-winter inspections, enhanced drainage systems, and the adoption of more resilient construction materials are both practical and economically feasible. Implementing these measures would primarily require improved oversight, as opposed to wholesale infrastructure replacement.

It should be acknowledged, however, that the present study is not without its limitations. The absence of destructive testing and continuous, year-round monitoring restricts the conclusiveness of some observations. Future research should incorporate advanced diagnostic techniques and a broader regional scope to validate and expand upon these findings.

The strengths of the study include context-specific observations and its practical recommendations for immediate improvement. Our results reinforce the importance of ongoing assessment and targeted maintenance, even for infrastructure elements

considered reliable. Through a sustained commitment to these measures, New Jersey barriers can continue to serve as effective safety features for years to come.

The findings suggest that proactive, targeted interventions can meaningfully prolong the service life of New Jersey barriers along the Corridor Vc. Post-winter inspections, prompt sealing of emerging cracks, and enhancements to drainage systems are especially effective in mitigating deterioration. Additionally, employing frost-resistant concrete, corrosion-resistant reinforcement, and adopting robust design profiles such as the F-shape are strongly endorsed to heighten durability.

Construction quality remains a decisive factor; many observed defects are attributable to preventable errors during implementation. Enhanced supervision, strict adherence to curing protocols, and improved communication between design teams and field personnel would likely diminish long-term vulnerabilities. Consistent monitoring incorporating condition rating systems and geotagged inspections supports data-informed maintenance strategies.

Looking ahead, infrastructure resilience should integrate climate adaptation measures. The study also underscores the importance of further research, including extended monitoring, laboratory experimentation, and exploration of smart sensor technologies to facilitate predictive maintenance. Ultimately, incremental improvements, rather than sweeping changes, present the greatest potential for gains in durability, safety, and cost-effectiveness.

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