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Landscape integration of retaining structures

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ABSTRACT: To implement the Swiss *Baukultur* Strategy and Landscape Concept in transport infrastructure, the Swiss Association of Road and Transportation Experts (VSS) issued technical recommendations for integrating landscape considerations into Swiss design standards for retaining structures (e.g., concrete walls, dry-stone walls, anchored walls, and nail walls). The guide consolidates national and international practices for the landscape integration of retaining structures, examining them from the perspectives of landscape characterization, construction techniques, maintenance challenges, and durability criteria. Special attention is also paid to the installation of photovoltaic panels on existing retaining structures. Drawing from this analysis, practical recommendations have been developed to provide analytical, organizational, and technical methods that facilitate the integration of new and renovated retaining structures into Swiss landscapes. Attention is given to the interplay of federal, cantonal, and municipal responsibilities. These recommendations ensure structural performance and durability while adhering to existing design standards. The methodologies, along with considerations for material selection, are illustrated through case studies, providing geotechnical engineers with a clear and reliable framework to ensure the effective landscape integration of retaining structures in Switzerland during the design, execution, and maintenance phases.

KEYWORDS: retaining structures, landscape, Baukultur, Switzerland, photovoltaic panels.

1 INTRODUCTION

In road and rail infrastructures, geotechnical retaining structures often have a significant visual impact on the landscape. In Switzerland, the Landscape Concept (FOEN, 2020) emphasizes the importance of preserving and enhancing the beauty and diversity of landscapes, ensuring that transport infrastructures are well-integrated and minimize landscape disruption. Additionally, the Building Culture Strategy (FOC, 2020) aims for high-quality construction projects tailored to their environment. In this context, the Swiss Federal Roads Office (FEDRO) and the Swiss Association of Road and Transportation Experts VSS launched a research project with the following objectives:

- summarize the international and Swiss state of the art regarding the landscape integration of geotechnical retaining structures;
- facilitate its effective implementation in new construction and renovation projects, enhancing project acceptability, evaluation by competent authorities, and building quality, with recommendations that are realistic and actionable, through the publication of a technical guide (FEDRO, 2026) (forthcoming);
- ensure its systematic consideration in projects through the inclusion of specific related requirements in the future version of the construction standard (VSS, 2002).

For retaining structures, there is a significant body of literature on the subject, especially in Switzerland, but it suffers from an overly sector-specific approach, being either very "landscape-oriented", as for example in (FEDRO, 2023), or very technical (Canton of the Grisons, 2018), but rarely both.

Special attention was also paid to the consideration of photovoltaic panels on retaining walls, for which practice is only just beginning (Swiss Confederation, 2020; Canton of Bern, 2022; Canton of the Grisons, 2022), and almost no extensive studies exist yet.

The main difficulty in developing recommendations lies in the subjectivity of landscape aesthetics: this technical guide therefore focuses on practical recommendations in the field of geotechnical engineering to better address the visual integration of retaining structures—both new and renovated—into the landscape, ensuring they are adapted to and coherent with their surroundings.

2 CONTEXT AND METHODOLOGY

In Switzerland, three distinct levels of administrative authorities—the federal government, the cantons, and the municipalities—are at certain points responsible for infrastructure ownership, including engineering structures, and their operation, as well as environmental protection, including landscape protection (see Section 4.2 below).

An important part of the research project methodology therefore consisted of discussions with representatives of these stakeholders within a working group to:

- gather information and feedback
- merge both (geo)technical and landscape protection states of the art
- suggest a project management methodology compatible with regulatory requirements

The approach adopted consisted of addressing the issue of landscape integration from the perspective of the civil or geotechnical engineer responsible for the project, while considering in parallel the landscape, technical, and administrative challenges in each project phase for both new structures and renovations, as summarized in Figure 1. The deliverables result in the technical guide (FEDRO, 2026), containing a bibliographic summary, a project management methodology, technical solutions, and illustrations using typical examples. The main highlights of this technical guide are summarized in the present article.

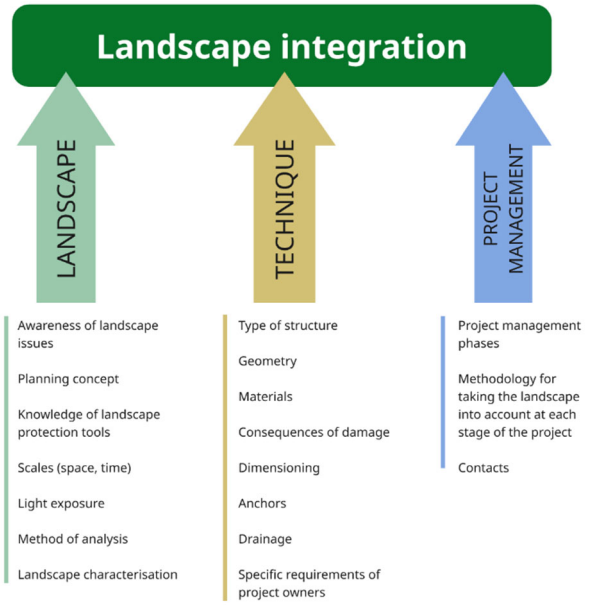


Figure 1. The three pillars of landscape integration for retaining structures

3 LANDSCAPE ANALYSIS

3.1 *Landscape characterization*

Landscape integration requires a prior characterization of the surrounding landscape. The research project results led to the recommendation that such an analysis be carried out using the landscape assessment method described in (FOEN, 2001) and (FOEN, 2005), and employing the terminology used in the landscape guidelines of the cantons where the project is located, mainly based on (FOEN, 2011) and (SL-FP, 2014), in order to consistently refer to similar landscape types. For example, according to (FOEN, 2011), Switzerland is divided into 38 landscape typologies within three major reference regions: Swiss Plateau, Jura, and Alpine region.

3.2 *Landscape protection*

In addition to their aesthetic characteristics, certain Swiss landscape areas are specifically protected at a national level (UNESCO; Federal Inventory of Heritage Sites of national importance ISOS; Inventory of Historical Traffic Routes IVS; Federal Inventory of Landscapes, Sites, and Natural Monuments IFP), at a local level (some IVS), or indirectly due to their unique biotopes (marshes, Swiss parks, etc.), as highlighted in Figure 2.

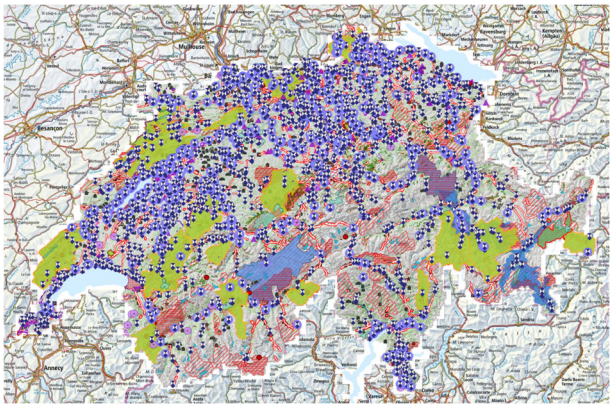


Figure 2. Example of the Swiss regulatory landscape protection map (map.geo.admin.ch, 2025). The colored areas indicate zones of direct or indirect (preserving local fauna and flora) landscape protection.

3.3 *Landscaping concept*

One of the outcomes of the research project is the recommendation to systematically define a *landscaping concept* during the planning (see also section 5.1) of new construction or the repair of retaining structures. This *landscaping concept* should be clearly and collaboratively outlined in the preparatory documents and describe the strategy and technical approach that the project owner intends to use to integrate the structure:

- In a specific landscape (part 3.1) with specific surroundings (other structures, buildings…)
- Possibly in a designated protection zone (Figure 2)
- For a given visibility strategy (Figure 3)
- According to different space and time scales (part 3.4)

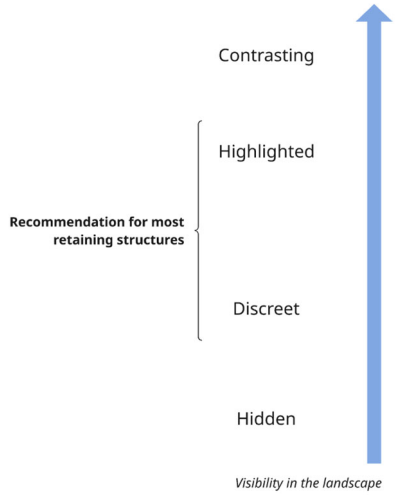


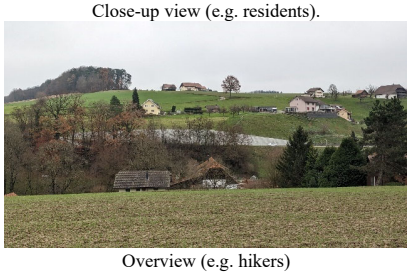
Figure 3. Visibility scale for retaining structures

3.4 *Different scales*

Different scales must be considered in landscape analysis:

- Space scale (Figure 4, ranked in order of importance): the structure does not appear the same depending on the viewpoint. The further away someone is, the more important the overall size and shape become.
- Time scale, with daily variations and seasonality (Figure 5). The surrounding landscape changes throughout the day (exposure to light, weather) and throughout the year (presence of foliage, colors, light, etc.). The integration of the structure into the landscape also changes with these elements.

Close-up view (e.g. residents).



Overview (e.g. hikers)

Infrastructure user's perspective

Figure 4. Space scale: several perspectives on the structure. Pictures: PPIC.

Spring / Summer Autumn

Winter

Figure 5. Time scale: appearance of a wall throughout the seasons. Pictures: PPIC.

4 TECHNICAL MEASURES

4.1 *Context*

The geotechnical constructive measures that ensure the stability and durability of retaining structures while also promoting their integration into the landscape were exhaustively studied in (Canton of the Grisons, 2018; Canton of Bern, 2023) and summarized below. Some of these measures (e.g., crest line of new structures) are explicitly included as requirements in the newly proposed method.

4.2 *Position of the structure*

In the context of new infrastructure, the layout should prioritize downslope retaining walls over upslope retaining walls. Downslope retaining structures are generally less visible to users, as they are often partially concealed by vegetation at their base (Figure 6).

Figure 6. Alternating upslope and downslope walls along a road. Picture: PPIC.

4.3 *Length and connection to the ground*

The length of the wall must be well proportioned to the height so that the wall appears stable and less massive. The walls must be long enough, as a wall that is too short appears poorly designed (Figure 7, right). The connections between the walls and the ground and the roadway must also be carefully designed (Figure 7, left).

Figure 7. Left: good connection at the ground level; right: Example of a wall that was too short and was extended in an unattractive manner. (Canton of Bern, 2023)

4.4 *Crest line and terracing*

The line of the crest of an upslope wall should follow the terrain but not strictly; it should form a consistent and regular line: a curve, steps, etc. (Figure 8 for a curved crest line). The crest line of a downslope wall should be straight and follow the infrastructure.

Figure 8. A good example of a crest line that follows the terrain harmoniously (Canton of Bern, 2023)

For walls over 3 m high, terracing should be considered to reduce visual impact and better integrate the structure into the slope. Berms at each level also allow for vegetation, softening the wall's appearance and enhancing landscape harmony.

4.5 *Structural material*

4.5.1 *Concrete*

The appearance of structural concrete has a strong influence on the aesthetics of a structure. Relief effects such as sandblasting, bush-hammering, coloring, and texturing, as well as the type of formwork (Figure 9), influence color and reflections. The concrete must be tested and adapted to the situation to match the landscaping concept choices.

Figure 9. Influence of formwork skin on the color of the concrete surface, after (BetonSuisse, 2020)

Special attention is also paid to the joints to ensure the aesthetic consistency of the wall surface while guaranteeing durability.

4.5.2 *Natural and dry-stone walls*

Natural stone retaining walls must be built using angular, locally sourced stones. A layered (multi-course) structure with regular horizontal stone courses is preferred, as it ensures structural stability and visual harmony (see Figure 10). The number, height, and arrangement of stone courses must be adapted to wall height, slope, and surrounding infrastructure.

Figure 10. Good examples of layered natural-stone walls (Canton of Bern, 2023).

Irregular (unshaped) stone layouts should be used only in non-urban areas or where similar walls exist nearby.

Joints between stones significantly impact the wall's visual quality. They should be fine, uniform, and proportionate to the stone size, and avoid vertical continuity (both horizontal for unshaped layout). Joint color should match that of the stones.

Dry-stone walls, built without mortar, are traditional elements of Swiss landscapes. Their construction requires skilled manpower and a larger budget. In protected heritage zones (e.g., IVS), dry-stone construction may be required to preserve historical and environmental values.

4.5.3 *Others*

Other structures such as embankments reinforced with geosynthetics/metal strips, biological engineering, prefabricated concrete elements, metal mesh, and shotcrete, in terms of their integration into the landscape, structural and construction aspects, and durability, are also detailed in (FEDRO, 2026)

4.6 *Facing and equipment*

4.6.1 *Greening*

The research project concludes that vegetation on retaining structure should generally not be prioritized. Although it can provide aesthetic and ecological benefits, successful growth requires careful planning, sufficient soil, irrigation, and maintenance. Vegetation often fails under harsh conditions and has a shorter lifespan than the structure. Excessive coverage can hinder inspections and damage materials. The study recommends focusing on designing high-quality, well-integrated structures without relying on vegetation. Greening is, however, a viable solution in urban areas, when carefully planned and maintained.

4.6.2 *Facings*

Facings, usually made of stone, can be used on structurally concrete walls. The aim is for the wall to look like a natural stone wall. To achieve this, the finish must look realistic: slight irregularities, texture, stones that increase in size from bottom to top, etc. are details that lend authenticity to the wall.

4.6.3 *Prestressed anchors*

When a retaining wall is equipped with anchorage tiebacks, the anchor heads must always remain accessible in Switzerland (SIA, 2013) for monitoring and potential maintenance. However, anchor heads are often visually prominent on the wall surface. This research recommends that, when technically and contractually feasible, visual impact can be reduced using recessed niches or removable covers (Figure 11)—provided accessibility is maintained.

Figure 11. On the left, the recesses obscure the anchor heads, but the shadow creates contrast; on the right, the metal covers make the wall uniform. Pictures: canton of Vaud, PPIC.

4.6.4 *Drainage elements*

Visible drainage elements, such as weep holes, must be carefully designed in terms of material, spacing, and height to ensure both functionality and aesthetic quality. Poorly planned systems (plastic pipes…) often lead to unsightly stains and a degraded appearance (Figure 12, left). Cement pipes (no metal reflection) cut parallel to the surface of the wall or masonry slots (Figure 12, right) are preferred solutions.

Figure 12. Left: retrofitted drainage system, with exposed piping and unsightly limescale deposits. Picture: PPIC. Right: a good example of drainage perpendicular to the wall via a vertical opening (Canton of Bern, 2023)

For upslope walls, it is recommended for new infrastructure to design the drainage system without visible weep holes to avoid potential surface water runoff deposits on the wall.

4.6.5 *Anti-fall equipment*

It is recommended to install fall arrest systems on upslope walls back from the crest. Additionally, using matte-finished structures is advised to reduce sun glare.

4.7 *Renovation*

The research project paid particular attention to renovation work, detailing the methods and procedures according to the nature of the intervention (full/partial renovation, minor repairs), the category of the structure, its nature, etc.

Local interventions on part of a structure should use techniques that achieve the same aesthetic result as the whole wall, for example, by using the same stones or joint color.

For full renovation, the principle is to maintain or improve the existing level of landscape integration. For example, aesthetic consistency must be ensured with other retaining structures located in the immediate vicinity on the same infrastructure.

5 PLANNING PERSPECTIVE

5.1 *Methodology*

A method has been suggested for each project phase (preliminary design, preliminary project, project, operation, maintenance…) after the Swiss construction project management standard (SIA, 2020), see Figure 1. This method

ensures compatibility between project management requirements, landscape analysis, geotechnical design and execution, operation and maintenance, as well as interfaces with the administrative authorities.

The method's complexity depends on the structure's *landscape integration category* defined in a similar way to the geotechnical category according to (CEN, 1997) and on the applicable landscape protection zone. It then involves defining the *landscaping concept* (see section 3.3), and implementing it through suitable construction methods, including collaborative steps such as engaging retaining structures inspection services from the design phase or involving residents in site visits.

5.2 *Example*

Figure 13 presents the starting flowchart for selecting the appropriate project management method. For instance, a retaining structure for a railway in a nationally protected area should follow the method corresponding to *landscape integration category C*.

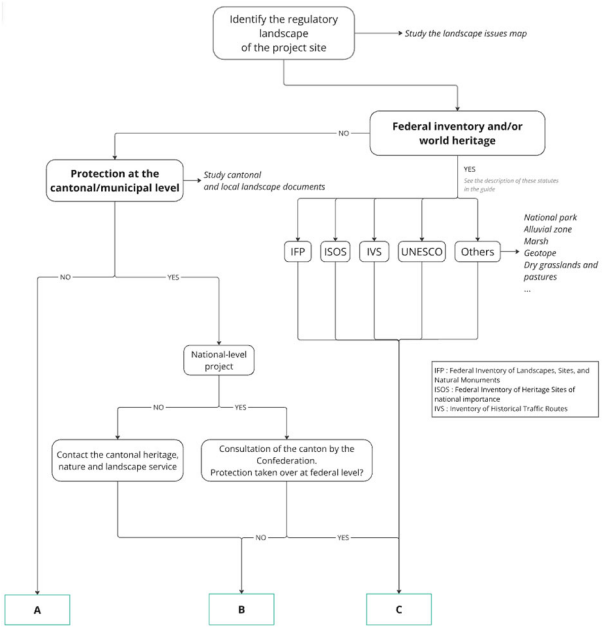


Figure 13. Flowchart for choosing a project management method that also considers the landscape integration requirements.

5.3 *Costs*

The additional costs related to the implementation of the recommended landscape integration measures are intended to be limited compared with conventional project expenses. For renovation works, they should remain within the usual budget, as the aim is to enhance existing structures without modifying their nature. For new constructions, the landscape integration category defines the scope of accompanying measures, such as landscape architect involvement, long-term photographic surveys, preliminary contact with authorities, etc., ensuring smoother approval by cantonal and federal authorities and ultimately reducing the risk of redesigns.

6 SPECIAL CASE OF PHOTOVOLTAIC PANELS

6.1 *Design*

The research project also focused on the installation of photovoltaic panels on existing retaining structures, mainly through feedback from pilot projects, e.g. (Baublatt, 2022).

The resulting design recommendations for landscape integration are to group the panels in a continuous manner that follows the contours of the wall and maintains alignment with the road (Figure 14), potentially using custom-shaped panels or even fake panels.

Figure 14. Photovoltaic pilot installation that follows the shape of the structure, with panels of different frame colors grouped together and parallel to the road. Picture: PPIC.

Verification of the wall's resistance to surcharge loads, along with a ferromagnetic inspection of existing reinforcements to ensure proper installation of the panels on the existing structure, is also mandatory (FEDRO, 2005).

6.2 *Color*

It is recommended to keep standard panel colors (black/dark blue) for good landscape integration, as these colors are also associated with photovoltaics and make it easy to identify the installation as such. The color of the panels must be the same for the entire installation or when several installations are located on the same section. It is also recommended to install panels without a metal-color frame and with a dark-colored background so that the modules do not contrast (Figure 14, on the left side).

Due to sun reflection issues, it is recommended to choose panels with anti-reflection treatment and to perform specific studies if the wall is subject to grazing sunlight.

6.3 *Maintenance*

The installation should be designed to ensure compatibility with maintenance tasks (vegetation maintenance; winter service), for example, by installing a protective rail under the panels to protect them from snow removal equipment (Figure 15 left). It is also recommended to use a system allowing quick removal or lifting of panels for visual checks of the wall (Figure 15, right).

Figure 15. Left: Installation protection and guidance system for winter service. Machines can move forward against the guardrail without damaging the photovoltaic panels. Right: individual lifting system for photovoltaic panels. Pictures: PPIC.

7 CONCLUSION

The conducted research project aimed to establish technical recommendations to ensure the proper integration of retaining structures into the Swiss landscape, also addressing the specificity of photovoltaic panels.

Its conclusions provide the first cross-cutting overview of the regulatory, technical, and landscape requirements for Switzerland, breaking them down into operational steps for the planning and execution phases. These recommendations are intended for incorporation into the new version of Swiss standard SN 640 383a, "Retaining structures: design, planning, and construction." (VSS, 2002).

The use of these recommendations will hopefully enable every project manager and geotechnical engineer to contribute to the preservation of Swiss landscapes while ensuring the optimal functioning of transport infrastructure.

8 ACKNOWLEDGEMENTS

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