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THE ACCEPTABILITY OF RETAINING-WALL SELECTION: A REVIEW

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Abstract: There are many types of lateral retaining systems (LRSs). Choosing the appropriate system is crucial as it depends on numerous factors. A precise understanding of these factors can significantly improve the engineering performance of LRSs, positively impacting engineering projects. Reviewing the most important factors related to selecting LRS and discussing some of their effects before choosing any one is highly beneficial for engineers. This review provides a concise summary of the most important factors based on a review of various literatures, presented in a readily accessible format to save time and effort. The factors considered include the wall's cost, function, operating time, construction feasibility, and materials. The most important presented factors related to the cost include appearance, configuration, overall stability, size and shape, flexibility, yield strength, movement, soil characteristics, and nature behind and under the wall, other consider actions included backfill material quality, construction requirements and methods, site obstacles and their nature. In fact, the system's flexibility affects its operating time as a support, some types of flexible walls are used in temporary applications, while rigid systems are typically designed for permanent purpose. Furthermore, important factors such as soil condition, aesthetics, drainage, and available construction and backfill materials may influence the choice of LRS. This paper provides illustrative examples demonstrating the impact of these factors on selecting the appropriate system.

Keywords: Retaining systems, cost, constructability, function, material, stablity.

Introduction

Retaining-walls, (RWs), or lateral retaining systems (LRSs), are engineering structures constructed to withstand the thrust exerted laterally by geomaterials, water, earth banks, grains, ore piles, coal, fill materials, or other supporting materials. The designer engineer must make several choices on the best RW. Particularly as the use of these structures continues to increase, accurate communication between these choices and project needs is essential. Crucial factors related to cost and technical viability are essential to the effective design of retaining structures. These factors are to be considered in the design process. They affect the type of RW and construction method (Hart, 2013; Al-Taie and Ahmed, 2025). Moreover, the creation of these factors is related to the assessment of the alternatives. They are both crucial, and their merits serve as a basis for methodically ranking available retaining systems. The retaining system's functionality and availability, constructability, appearance, etc., all influence the total cost (NCMA, 2009; Al-Taie and Ahmed, 2024).

To assist the designer in the early stages of design, the current review examines aspects of significance that influence the acceptability of the selection of the proper retaining wall. It provides a concise summary of the most important of these factors based on a review of various literature and summarizes them in a way that makes them readily available, thus saving effort and time. As illustrated in Figure 1, the factors chosen for this review include the wall's cost, function, operating time, constructability, and material.

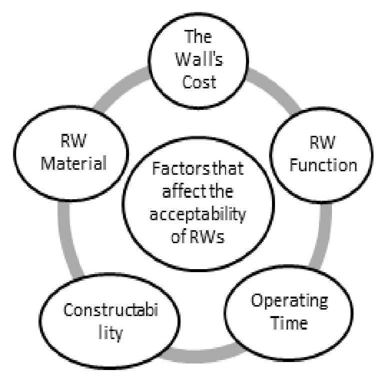

Fig. 1. Factors' presented in the current investigation.

Retaining Wall's Cost
Cost should be the first consideration when choosing a retaining wall. This review highlights its significance in selecting an appropriate earth retention system. In civil engineering, structural design typically involves both direct and indirect cost components (like controlling and manufacturing of RWs, environmental aspects, and construction and design). It is important to distinguish between these costs in the retaining systems. The first is related to anything concerning the construction, such as the materials, labor, equipment, and site preparation. While the costs related to the engineering and design, permits and fees,

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Table 1. Categories of retaining systems based on their cost.

Categories	**The retaining system**				
RWs with "very low" cost	Geosynthetic group of RWs with different faces as below				
	welded wire- face		concrete-face	geosynthetic- face	
RWs with "low" cost	walls of a timber crib	Rock or (rockeries) walls	reinforced-soil of welded wire-faced steel	Reinforced-soil slope	Reinforcement soil segmental RWs
RWs with "relatively low" cost	Soil nailed retaining systems	Modular concrete —panel, steel reinforced —soil walls	Concrete bin RWs	Concrete crib RWs	Concrete— faced steel reinforced — soil system, and RWs of metal bin
RWs with "low-to-moderate" cost	Sheet pile RWs				
"moderate-to-high" cost	Gabion RWs	Welded-wire concrete-panel steel reinforced-soil	Metal crib RWs	Anchored wall systems (deadman— Non-gravity type)	
RWs with "high" cost	Soldier— piles system	Concrete counterfort RWs	Concrete (gravity and cantilever) RWs	Masonry (mortar-rubble) walls	
RWs with "very high" cost	Non— gravity type (tie— back) anchored RWs			Cylinder pile— walls	

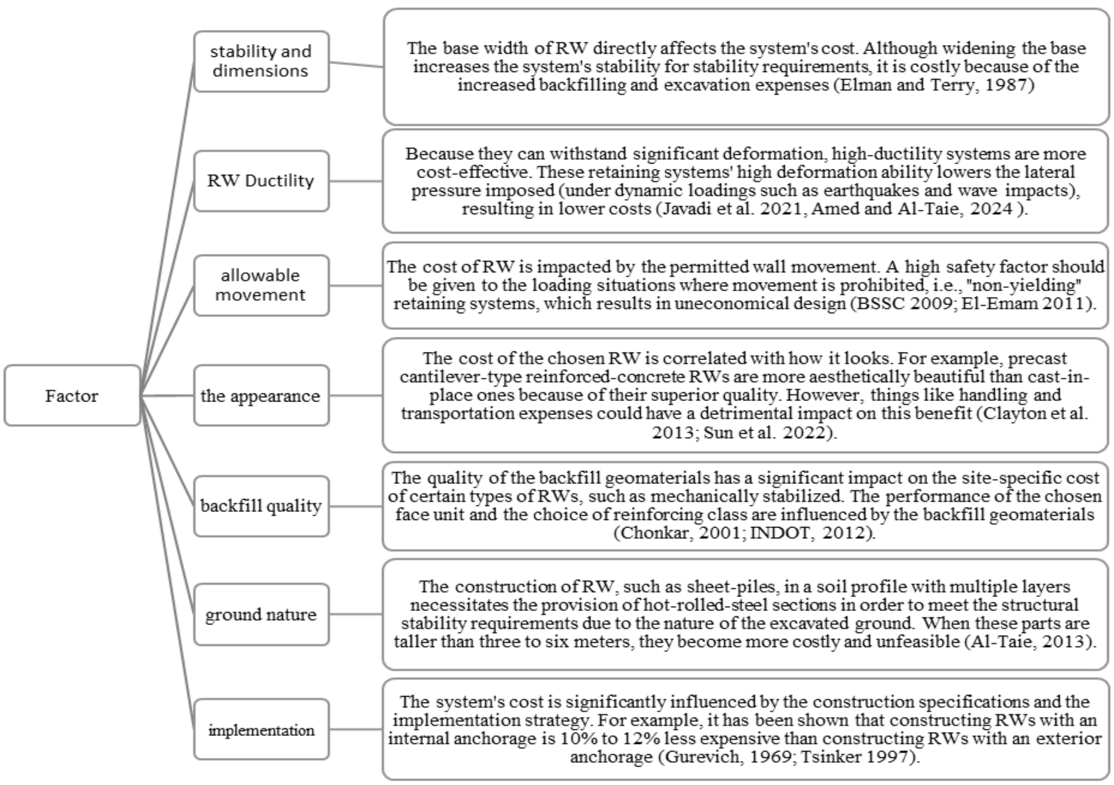

Fig 2. Several instances of factors influencing the RW cost.

site management and safety, business overhead, and all costs required to execute the project are indirect. In other words, issues related to control, manufacturing, failure, environment, and maintenance are among the indirect cost components, the direct cost is associated with construction costs (Hueting, 1974; Stuip, 1980; Field, 1994; Van Der Toorn, 1994; Koseki *et al*., 2006; Mikk, 2025). Based on the cost, the RWs can be practically categorized into six groups. These are:

- very-low cost
- low cost
- low to moderate cost
- moderate to high cost
- high cost
- very high cost

When selecting an RW, cost is a major factor. As shown in Table 1 (Koseki *et al*., 2006; WSDOT, 2009), different kinds of earth retaining systems were categorized in this

Table 2. Functions of the retaining system: Examples ((Bakker, 2000).

Retaining System Function		Deep excavations					Quay wall				Locks			
		Sheet pile	Piled-wall	Berlin wall	Combined wall	Deep wall	Cell dam	Guide wall	Coffer dam	Combined wall	Anchor wall	Seepage screen	Guide wall	Chamber wall
Main function	Soil Retention	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
	Water Retention	✓	-	-	✓	✓	-	-	-	-	-	✓	-	✓
	Erosion protection	-	-	-	-	-	-	-	-	-	-	✓	-	-
	Water tightening	-	-	-	-	-	-	-	-	-	-	-	-	-
	Guidance	-	-	-	-	-					-	-	-	-
	Horizontal Bearing	-	-	-	-	-	-	-	✓	-	✓	-	-	-
	Vertical Bearing	-	-	-	-	-	✓	✓	✓	✓	-	-	-	-
Secondary function	Soil Retention	-	-	-	-	-					-	-	-	-
	Water Retention	-	✓	-	-	-	✓	✓	✓	✓	-	-	✓	-
	Erosion protection	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	✓
	Water tightening	-	-	-	✓	✓	✓	✓	✓	✓	-	✓	✓	✓
	Guidance	-	-	-	-	-					-	-	✓	✓
	Horizontal Bearing	✓	✓	✓	✓	✓	✓	✓	-	✓	-	-	-	✓
	Vertical Bearing	✓	✓	✓	✓	✓	-	-	-	-	-	-	-	-

review based on the aforementioned categories and the literature.

Numerous factors influence the cost of a retaining system. Some of them are closely related to the support wall itself, and others are related to the surrounding environment and project requirements. The appearance, configuration, global stability, size and shape, ductility, yielding, and movement are among the factors related to the retaining system itself. Meanwhile, the properties and nature of the soil behind and beneath the wall, the quality degree of the backfill geomaterials, the requirement of construction and adopted method, and obstructions in situ and their nature are direct factors related to the surrounding environment and the project. The flowchart in Figure 2 with notes explains how some of these factors affect the cost and how they relate to one another. It is important to note that, according to the suggested retaining method, each of these factors affects the overall cost.

For instance, when the chosen retaining structure requires substantial amounts of high-quality backfill material (e.g., the mechanically stabilized systems), factors related to the quality of the backfill soil are crucial in deciding the final cost. Remember that it's not always possible to find high-quality geomaterials close to a designated construction site. In these situations, it is vital to look at and investigate the possibility of adopting available options (from natural, artificial, byproduct, or waste materials) as backfill in an effort to lower the overall cost. Sedimentary soils, aeolian soil (naturally occurring), windblown soils, dune sand, a range of industrial wastes, and waste materials are a few examples of these endeavors (Al-Taie, 2002; Al-Taie and Al-Shakarchi, 2016; Li *et al*., 2020; Prajapati and Rangwala, 2022; Ahmed and Al-Taie, 2025).

Retaining Wall's Function

When choosing the RWs, the functional values play a significant role. Table 2 lists various roles for which retaining systems are used. In addition to serving as soil and/or water retention, RWs can be employed as guides, rockfall barriers, erosion control, load carriers, slope stabilization, waterproofing, and impact energy absorbers (Chonkar, 2001; Xiao and Barreto, 2015). Furthermore, they can be employed to prevent landslides, provide support on unstable-ground, screen seepage, build bridge abutments, chamber walls, bank and coastal protection, building sides, quay walls, locks, toe protection, dam construction, auxiliaries, flood control, deepened roads, isolation, skirts, screen guiding, dike reinforcement, and for environmental applications.

They are also utilized in traffic underpasses and highway and railroad projects to preserve the transition between various levels. To link several highway means and adjacent earth surfaces, to conserve the roadbed slope-foot, to speed up the construction period of the projects, to lessen land-take, to decrease excavated slopes' height, to deny the roadbed from the impact of water-washing, and for issues related to aesthetic enhancement (Bakker, 2000; Codutu, 2001; INDOT, 2012; Bentler and Labuz, 2006; Huang and Luo, 2009; Ertugrul *et al*., 2017; Choudhury and Rajesh, 2020; Javadi *et al*., 2021; Lu *et al*., 2023).

Another crucial role of piled-wall systems (contiguous and secant piles and diaphragm systems) is the underpinning support. In order to maintain the existing foundations next to the excavation work for a basement, piled-wall constructions frequently serve this purpose. Additionally, in water-bearing circumstances, it is preferable to employ a piled-wall as protection against ground loss (coarse-grained ground). However, retaining systems can be utilized for many functions, concurrently, including one or more primary duties as well as one or more supplementary functions (Table 2), (Bakker, 2000; Clayton *et al*. 2013; Tomlinson and Woodward 2015; Ferdous *et al*. 2018; Salgado 2022).

Retaining Wall's Operating Time

Time is crucial for choosing the RWs, according to the structural analyst's viewpoint. There are two types of retaining systems: "permanent" and "temporary." In temporary operation, the RW acts as a shoring system for a shortened time to supply dry-working conditions and safe support whilst other infrastructures and installation activities are constructed; otherwise, a huge excavation is needed. In permanent construction, the RW is utilized to supply a permanent workspace needed for various reasons (e.g., parking, subway stations, etc.) or to provide support to engineering-works like bridge abutments, basements, harbor walls, highway cuttings and, dock walls, etc. (Atkinson 2007; Salgado 2022).

Some retaining systems are suitable for permanent retaining activities such as in concrete cantilever systems, concrete counterfort systems, concrete gravity systems, bin and crib walls, gabion-type walls, mechanically -stabile systems with precast facing, noise walls, guide stable, and chamber walls. Whilst other forms of retaining systems are more suitable for temporary retaining issues. The materials used to make or construct the RW may have a high impact on its operation, e.g., wooden sheet-piles are used only for temporary support in light-structures built above the groundwater table (Bakker 2000; Gazetas *et al*. 2004; Das and Sivakugan 2019).

But some retaining systems (such as mechanically-stabilized with (geotextile, welded-wire face, geogrid), reinforced-soil slopes, lagging walls, soldier and sheet piles, and soil-nails) can be utilized for both permanent and temporary operation (Table 3) (Xiao and Barreto 2015). It is worth mentioning that the system's flexibility affects how long it can function as a shoring. While some varieties of flexible walls are utilized for temporary operations, rigid systems are typically intended for permanent purposes. The RW meant to be permanent supports have a different design approach from that of the temporary ones. Traditionally, temporary systems are less mechanically rigid than permanent ones, which are costlier and more rigid.

Additionally, temporary retaining systems with adequate stiffness and strength (such as slurry RW, diaphragm walls, and secant walls) can be formed or later integrated into the built structures. Consequently, increased efficiency for the built facilities can be attained (Holtz *et al*. 2023). However, the amount of time for building is a crucial consideration when choosing the kind of retaining system. While some systems are built quickly, others take a long period. While walls like metal bins, concrete cribs, soldier and sheet piles, and nailed soils can be built in a short construction period, but walls like concrete and counterfort gravity take a long time to build. Additionally, precast retaining types, namely cantilever walls of modest height, can be employed for rapid on—site assembly (Kaniraj 1998; Bakker 2000; INDOT 2012; Clayton *et al*. 2013; Das and Sivakugan, 2019).

Table 3. Examples of permanent operating and/or temporary operating use of retaining systems.

Retaining system	permanent operating	Temporary operating
Deep wall	✓	
Combined wall	✓	✓
Coffer dam	✓	
Isolation RW	✓	
Guide wall	✓	
Piled wall	✓	✓
Anchor wall	✓	
Noise RW	✓	
Deep wall	✓	✓
Cell dam	✓	
Steel sheet pile		✓
Guide wall	✓	
Berlin wall		✓
Combined wall	✓	
Seepage screen	✓	

Retaining Wall's Constructability

Retaining systems can be divided into two primary categories according to the construction approach: "fill-section" and "cut-section". The fill-section type, often known as "bottom-up construction," builds from the bottom to the top. The following types are examples constructed by fill-section type: semi-gravity and rigid systems like (concrete counterfort, gravity, and cantilever walls), reinforced-soil slope, reinforced-backfill retaining systems such as mechanically- stabilized or precast and segmental faces, pre-fabricated modular-gravity RWs like (bin and crib walls, and gabion RWs), geotextile and geogrid systems, and welded-wire facing RW.

Because the "cut-section" type is constructed from top to bottom, it is known as "top-down construction." This category comprises in-situ reinforced RW (soil-nailed), non-gravity cantilevered-walls (intermittent, secant, and contiguous piled-walls, and drilled-shaft), sheet-pile and soldier-pile walls, and lagging walls (Hart 2013; Codutu, 2001; Briaud, 2023). It is significant that for the mentioned construction method, important factors like soil condition, aesthetics, and drainage condition may dominate the kind of retaining system chosen.

For example, based on the aforementioned variables, the drilled shaft walls may be built as secant with interlocking piles, contiguous with small gaps, or intermittent with significant spacing between piles. Intermittent pile walls are used in overconsolidated soils where the subsurface water-table is below the excavation-level, or in soils with significant cementation. Contiguous pile walls can be used in very-low permeability soils, and secant pile walls can be used to produce RWs with a high degree of water tightness (Fig. 3) (Clayton *et al*, 2013).

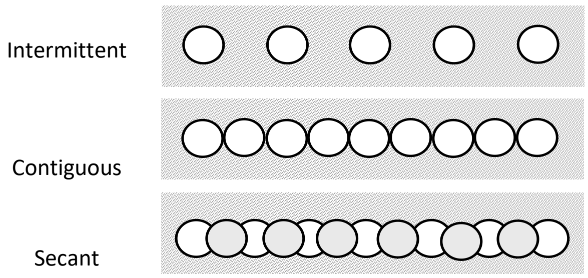

Fig. 3. Various configurations bored pile-RWs (Clayton et al., 2013).

The retaining systems that are backfilled with backfill geomaterials (cohesive or non-cohesive) are expected to have a different loading experience than those that maintain the original or native soils (Wagner and Sitar 2016). In fact, issues pertaining to the subsurface characteristics, environmental impact, and construction conditions may influence the choice of the proper installation technique (Clayton *et al*. 2013; Takuma *et al*. 2015). There are two options for the implementation of cantilever retaining systems with anchorage: exterior anchorage and internal anchorage. In fact, the subsurface characteristics can influence the construction technique; the RW with external anchorage is recommended for a poor soil foundation. One benefit of using external anchorage is that it results a homogeneous distribution of bearing stress beneath the base of the retaining system (Tsinker, 1997).

Retaining Wall's Material

Retaining systems are constructed from a range of materials, mostly because of their extensive use in various ground conditions and circumstances. They are generally made of concrete, brick, stone, or steel. Typically, reinforced concrete is used to build the cantilever and counterfort walls. However, materials other than steel or concrete can be used to create a group of retaining systems, whose stability is derived from the principle of gravity. Granular materials reinforced by synthetic polymers, such as geo-textiles, polymer grids, sheets, meshes, or metal strips, are employed in mechanically stabilized systems.

Gabion RWs can be made from wire baskets filled with rock, granular material, or cobbles. However, the crib walls can be built with granular materials to fill box members composed of plastic, concrete, metal, precast blocks, wood, or metal. Additionally, another type of gravity systems is a drystone retaining wall, which is made of well-stacked stone without the need for mortar. They are extensively utilized to support terraces for buildings, roadways, agriculture, and highways in nations like the UK and France. Additionally, brick is a cost-effective material that works well for masonry RWs with modest heights and can be an appealing building material (Kaniraj, 1998; O'Reilly *et al*, 1997; Odent, 2000; Chonkar, 2001; Clayton *et al*, 2013; Le *et al*, 2014; McCombie *et al*, 2016).

However, alternative materials can be used to build retaining systems that manage their stability from embedment depth below the dredge-line. Steel, precast concrete-panels, wood, vinyl, plastic, aluminum, polyvinyl chloride (PVC), and fiberglass are utilized in the production of various sheet-pile systems cross-sections. Whilst secant and contiguous piles, and diaphragm walls are constructed using both reinforced and plain concrete (Haseltine and Tutt, 1977; Bakker, 2000; Codutu, 2001; Turner, 2009; Brooks, 2010; Takuma *et al*, 2015; Das and Sivakugan, 2019).

The goal of constructing the retaining system is the primary factor in choosing the right materials. However, choosing an appropriate system requires a thorough grasp of the distinctions between various construction materials, their special qualities, and their benefits and drawbacks. For instance, materials like steel and wood are likely to be impacted by corrosion (for walls made from steel) and decay or animal attack (for walls made from timber) when rebuilt in coastal locations, such as seawalls. In such a situation, special considerations to improve the durability of the retaining system—such as cathodic or coating protection for steel-made walls—must be included at an extra expense. Concrete, an alternate material that is less prone to deterioration, would be more suited for water RWs, but it has drawbacks in terms of constructability because it is difficult to lay fresh concrete underwater (Thomas and Hall 2015; Smith 2016; Marcinkowski and Gralewski 2020).

Conclusion

There are many types of retaining systems. Choosing the appropriate system is crucial as it depends on numerous factors. This review paper provides a concise summary of the most important factors based on the literature and scholars. As was discussed in this investigation, some of these parameters are associated with the cost of the chosen wall, its function, the duration that the retaining system operates, the constructability, and the material used in construction.

By adopting RW with relevant ductility, significant deformation resistance is achieved, thus making it more cost-effective. In turn, the allowable movement of the system is a sensitive factor affecting the selection, where "non-yielding" RWs cause uneconomical design. In fact, the system's flexibility affects the retaining system's operating time as a support. Some types of flexible walls are used in temporary applications, while rigid system are typically designed for permanent purposes. Furthermore, it appears that the selection of RWs is impacted by important factors such as soil condition, aesthetics, drainage, functional values, operating time, and available construction and backfill materials. In fact, choosing an appropriate RW requires a thorough understanding of the distinctions between various factors and their special impacts.

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