

Technical solutions for reducing CO₂ footprint in MSE wall constructions

Anaïs Grandclerc^{1*} and Thomas Joussellin¹

¹Terre Armée, Technical department, 92500 Rueil-Malmaison, France

Abstract. Today, the construction industry is one of the most CO₂-emitting sectors. Actions have been taken for several years to reduce these emissions, but progress is still being made to reach the global greenhouse gas emission reduction targets. Reinforced earth walls are mainly composed of a facing made of concrete or welded mesh panels with a backfill reinforced by metallic or geosynthetic elements. This article deals with the proposal of technical solutions to reduce each component's carbon footprint of a reinforced earth wall (facing, reinforcement, backfill) and to estimate the CO₂ emission reduction at the construction project level (calculations based on a specific and real construction project). Concerning the concrete panels, the replacement of ordinary Portland concrete by low-carbon concrete is a key parameter in the reduction of CO₂ emissions of the construction of a reinforced earth wall (estimation of reduction between 15% and 30% on the total CO₂ emission for this project). Regarding the backfill reinforcement, using geosynthetic reinforcement instead of steel reinforcement is also a way to reduce CO₂ emissions. Indeed, steel reinforcements accounts for around 20% of total CO₂ emissions for this project while geosynthetic reinforcement accounts for around 5%. Finally, regarding backfill, its carbon impact represents about 45% of this project's overall CO₂ emissions, considering the materials and their transportation. Thus, using recycled materials as backfill and reducing transportation distance are essential.

1 Introduction

Progress is still being made to reach the global greenhouse gas emission reduction targets in the construction industry which represents 6 to 8% of total GWP emission worldwide [1].

MSE wall (Reinforced Earth wall) components are divided into three parts (Figure 1):

- Facing made of concrete reinforced by steel or steel welded mesh panels.
- Backfill (technical backfill).
- Steel or geosynthetic reinforcements for the backfill.

MSE walls are one of the least CO₂ intensive earth retaining structures.

* Corresponding author: anaïs.grandclerc@terre-armee.com

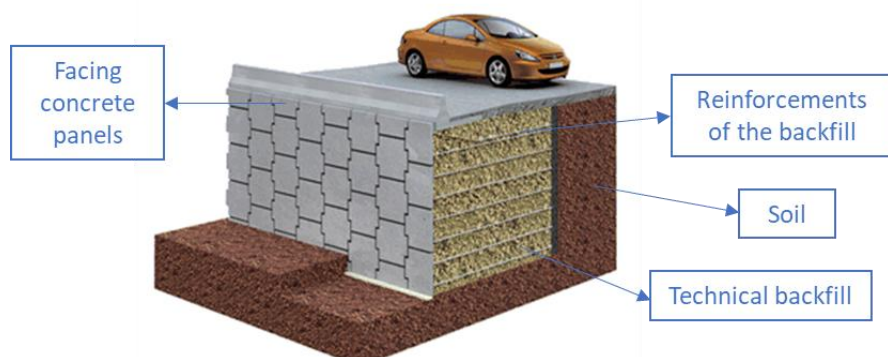


Fig. 1. Description of MSE wall.

For this study, a real construction project is used. The CO₂ emissions associated with this construction project will be calculated considering the CO₂ emission related to material manufacturing and transportation from the manufacturing plants to the construction sites. Then, alternatives will be proposed with technical solutions that emit less CO₂.

2 Carbon footprint of the MSE wall considered for this study

The construction project considered for this study is a MSE wall composed of reinforced concrete panels as facing, geosynthetic straps as reinforcements of the backfill and backfill.

The quantities used for this project are presented in Table 1 and in Table 2 and are calculated for 1 m² of wall. These quantities are extracted from a typical design for MSE wall. The emission factors used to calculate the carbon footprint of this project are presented in Table 3 and are extracted from several databases (the references used are in the last section).

Table 1. Geometrical dimensions of the wall and quantities of materials for 1 m² of wall.

Designation	Quantity
Surface considered	1 m ²
Average height	4 m
Average depth	5 m
Total length of backfill reinforcement – geosynthetic	14 linear meters
Weight of technical backfill	7.5 tons
Steel density in concrete (94% recycled)	4.9 kg

Table 2. Transportation of materials from the manufacturing plants to the construction sites.

Materials	Type of transportation	Distance (km)
Facing panels	Truck	150
Geosynthetic reinforcements	Truck	500
Technical backfill	Truck	20

Table 3. Emission factors used in this study.

Materials	Emission factors	Unit	Database
Concrete panels	308	kgCO ₂ e/m ³	[2]
Steel in concrete 94% recycled	0.78	kgCO ₂ e/kg	[3]
Geosynthetic reinforcements	0.30	kgCO ₂ e/lm	[4]
Backfill	4	kgCO ₂ e/t	[5]
Steel straps (galvanized steel) – 15% recycled	2.46	kgCO ₂ e/kg	[3]
Emission factor for road transportation	0.089	kgCO ₂ e/(km.tons)	[5]

To calculate the CO₂ emission for each component of the MSE wall, the quantities of each material should be multiplied by the emission factor defined in Table 3. For the calculation of transportation from the manufacturing plant to the construction site, the quantities of each material should be multiplied by the emission factor defined in Table 3 (0.089 kgCO₂e/(km.tons)), and by the distance covered by each component.

The results obtained for this construction project is equal to **99 kgCO₂e/m² of MSE wall**. CO₂ footprint of components (manufacturing and transportation from the manufacturing plants to the construction sites) of MSE wall are broken down as follows (Figure 2):

- 50% for concrete reinforced by steel panels.
- 4% for reinforcement of backfill.
- 46% for backfill itself.

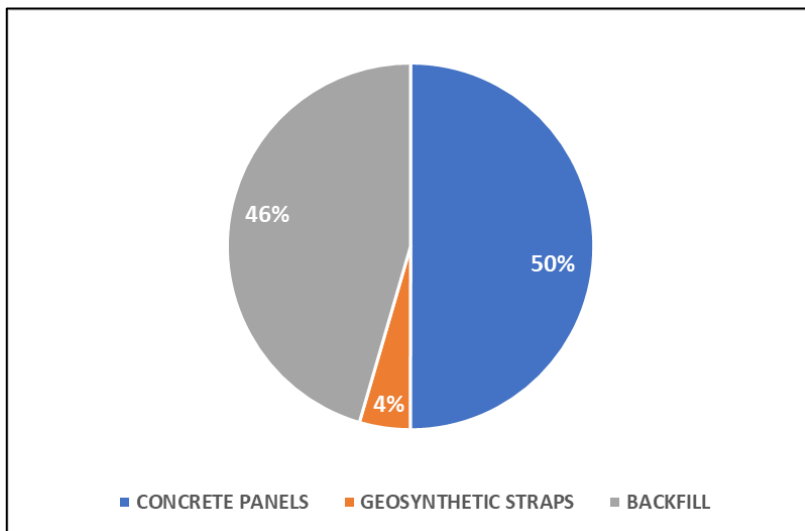


Fig. 2. Breakdown of CO₂ emission of a MSE wall specific project.

3 Impact of less CO₂-emitting solutions

3.1 Facing panels

In this part, the impact of using low carbon concrete is studied. Three categories of low carbon concrete are defined in terms of emission factors for concrete with a compressive class strength between C35/45 to C45/55 (MPa), which is the most common strength class used for concrete panels in MSE applications (Table 4). The emission factors are extracted from Exegy solutions [2], which is a complete construction solution that aims to generalise the use of low-carbon concretes on construction sites.

Table 4. Emission factors for three low carbon concrete categories according to [2].

Category	Emission factors minimum	Emission factors maximum	Unit
Classic concrete	240	-	kgCO ₂ e/m ³
Low carbon concrete	175	240	kgCO ₂ e/m ³
Very low carbon concrete	120	175	kgCO ₂ e/m ³
Ultra-low carbon concrete	-	120	kgCO ₂ e/m ³

The impact of using low carbon, very low carbon, and ultra-low carbon categories on total CO₂ emission of a MSE wall is proposed in Table 5.

Table 5. Impact of using low carbon concretes on the CO₂ emission of a MSE construction project.

Category	Emission factors (kgCO ₂ e/m ³)	Total CO ₂ emission (kgCO ₂ e) for 1m ² of MSE wall
Classic concrete	308	99
Low carbon concrete	200	84
Very low carbon concrete	150	77
Ultra-low carbon concrete	100	70

The use of low carbon concrete reduces the carbon footprint of the entire project by 15% for low carbon concrete, 22% for very low carbon concrete and 29% for ultra-low carbon concrete.

3.2 Reinforcement of backfill

In this part, the impact of using galvanized steel straps with 15% of recycled steel instead of geosynthetic straps is studied. The results are presented in Table 6.

Table 6. Impact of using steel straps instead of geosynthetic straps on the CO₂ emission of a MSE wall construction project.

Type of reinforcement	Emission factors (kgCO ₂ e/kg)	Total CO ₂ emission (kgCO ₂ e) for 1m ² of MSE wall
Steel straps (15% recycled)	2.46 [3]	122
Geosynthetic straps	3.3 [4]	99

The use of geosynthetic straps reduces the carbon footprint of the entire structure by 23% compared to the use of steel straps with 15% of recycled steel.

3.3 Backfill

This section examines the CO₂ footprint impact of the distance of transportation for backfill.

As mentioned in section 2, backfill represents 46% on the total CO₂ emission of the specific MSE wall construction project considered in this study and 31% of the CO₂ emission from the backfill is occupied by the transportation to the construction site.

Table 7 presents the study of the impact of transportation distance on the CO₂ footprint of the structure.

Table 7. Impact of transportation distance of backfill on the CO₂ emission of a MSE construction project.

Distance of backfill transportation (km)	Total CO ₂ emission (kgCO ₂ e) for 1 m ² of MSE wall
20	99
50	119

It is important to use a fill material from the closest possible source to the construction site, as increasing the transportation distance from 20 to 50 km increases the project's CO₂ emissions by 20%.

Other alternatives exist, such as increasing the amount of recycled steel in steel straps or replacing the steel reinforcement in panels with glass or basalt fibers reinforcement or using recycled materials such as crushed concrete as backfill.

4 Conclusion

The three alternatives proposed have a significant impact on the total CO₂ footprint of a MSE wall. Indeed, the calculation of the carbon footprint with the most polluting assumptions (steel straps, conventional concrete for the panels, 50 km for the transportation of the backfill) results in a total CO₂ emission of 142 kgCO₂e, while for a project with the least polluting assumptions (geosynthetic straps, ultra-low carbon concrete, and 20 km for the transportation of the backfill), the total CO₂ emission is equal to 70 kgCO₂e.

This study demonstrates that feasible solutions can significantly reduce the carbon emissions of a MSE wall.

Acknowledgements. This study has been carried out inside TERRE ARMÉE company. No external financial support was provided.

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