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RESEARCH ARTICLE

Observation of Remedial Works on Failed RC Wall with Innovative EC Geoblock Gravity Retaining Wall

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ABSTRACT - The paper presents an overview of the construction of a novel EC Geoblock gravity retaining wall intended as a restorative measure to repair a collapsed reinforced concrete (RC) wall. The construction process, including site preparation, pad levelling, block installation, backfilling, and final finishing, is thoroughly covered in the article. This article aims to demonstrate the effectiveness, efficiency and swift implementation of remedial works on collapsed RC wall. The gravity wall's distinctive design elements, which improve its cost efficiency, structural integrity and drainage ability are highlighted. The study also examines the benefits of this novel approach over conventional RC walls, including its shorter construction time and environmental friendliness. By offering a novel construction idea, this ground-breaking block design promotes sustainable development and helps achieve SDG 9: and SDG 11. Moreover, the post project checks on the deflection are less than 10mm which further showed the structural soundness of the novel EC Geoblock gravity retaining wall.

ARTICLE HISTORY

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1. INTRODUCTION

Retaining walls are structures designed to hold the lateral force created by soil behind it. However, the wall can fail due to the results of inadequate design or the improper construction of the wall. Common failures of retaining wall structures are overturning failures, sliding failure and bearing failures of soil and are often consider in the design of retaining structures [1-3]. Moreover, poor drainage and built-up pore water pressure is the leading cause of failure for many retaining walls. A reinforced concrete wall has failed in MIEL Industrial Estate, Bandar Baru Bangi, Selangor Darul Ehsan on 10 November 2021 and EC geoblock gravity wall was adopted as a remedial solution to the failed area. EC GeoBlock System is a Malaysian Technology in retaining wall field. The EC GeoBlock System consists of E and C Precast Block. It is developed to be light for easy handling, quick and simple interlocking construction to form a flexible, strong and durable wall. Gravity retaining walls resists the lateral earth pressure only though their self-weight [4]. There are one of the oldest types of retaining wall which can be dated back to the ancient time of Egypt where Egyptian employed the gabion style retaining wall which is a type of gravity retaining wall to divert the water flow of the Nile River away from the field to minimize the occurrence of flooding and erosion to soil in the proximity of the river [5]. Today, gravity retaining wall continue to be used in current small to large-scale project with more refine and efficient design methods.

There are several types of gravity retaining wall which includes cast-in-situ, gabion, crib and segmental precast modular block gravity retaining wall. Cast in-situ gravity retaining wall are constructed directly on-site. The construction process involves building a temporary formwork, pouring of concrete and adding of reinforcement. The temporary formwork is removed once the concrete cure, leaving behind a hardened solid concrete gravity retaining wall. Since, the wall is cast on site, the wall is highly dependent on weather condition and difficult to ensure good quality. Gabion gravity retaining wall are walls comprise of wire mesh box filled with different size rocks. Gabion gravity retaining wall is more prone to corrosion than concrete wall due to the metal wire mesh as shown in study conducted by [6] along with other form of failure in gabion wall. Crib gravity retaining wall consists of precast concrete header connect with precast stretcher block to form a crib like structure. The arrangement of each components form a space where grass, flower [7], gangue [8] or other suitable material can be filled for better aesthetic appeal. However, the slanting nature of the crib wall, there are chances of exposed filled material falling off the crib wall as the wall weathered [9] .Precast segmental modular gravity retaining wall is another type of retaining structure that composed of precast block that connect through interlocking between blocks are through shear keys or other adhesive material. Precast segmental modular gravity retaining walls are constructed by stacking precast concrete blocks piece by piece. All walls mentioned are gravity retaining walls as they significantly rely on mass to resist the lateral pressure from earth.

The filling material for retaining wall heavily affect the overall performance and stability of the wall [10]. Granular material have always been widely used as filling material due to their excellent drain performance [11]. On the other hand, there is a growing trend towards using more sustainable materials, such as recycled tire chips [12] ,Bottom ash [13]

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and more as backfill material for retaining walls. This shift emphasis the importance of environmental sustainability and the need to reduce waste. The usage of sustainable filling material alternatives can minimize the impact to the environment while providing more innovation to the design and construction of retaining wall. Long term stability of the retaining wall highly influenced by its drainage performance. The shear strength of the soil is reduced when there is excessive pore water pressure resulting possible structure failure. Hence, the selection of filling materials plays a crucial role in ensuring sufficient drainage. Malaysia's tropical climate especially in monsoon seasons pose significant threat to structures, particularly in retaining wall. The aftermath caused by poor drainage management can be dangerous, an example of retaining wall collapse at Puncak Setiawangsa, Kuala Lumpur that occurred in 2012 have led the evacuation of 88 residents [14].The cause of this tragedy is mainly due to the poor drainage management as the shotcrete retaining wall failed to divert the surface runoff from rainfall which generate excess pore water pressure resulting in the collapse of retaining wall. By prioritizing drainage and selecting appropriate backfill materials, the risk of wall failure can be significantly mitigated [15]. Several recent cases of retaining wall failure due to heavy rainfall have occurred across Malaysia including the collapse of a 105m long retaining wall in Pengerang, Johor on January 2022, the collapse of retaining wall at Taman Bunga Raya, Jalan Genting Klang on August 2024 and more causing property damage and anxiety of the affected residents [16,17]. While conventional gravity retaining wall have been used widely, there often suffer from limitations including poor drainage management, erosion issue and aesthetic constraint. Even though crib wall is permeable, it is susceptible to vandalism and is difficult to handle due to the small size of header and stretcher [18]. It is labour intensive to construct cast-insitu wall and the quality is not always assured. While gabion wall is flexible, it is highly prone to corrosion and have risk of rocks falling of the wire mesh. Precast segmental modular gravity retaining wall often comes in large sizes which required large machinery or size too small which cause difficulty in handling.

This paper will discuss on the new EC Geoblock precast concrete. The innovative new EC Geoblock gravity retaining wall are self-interlocking without the needs of adhesive material and contains space in between blocks which can be infilled with granular material for better drainage performance. Due to the reasonably size EC Geoblock, they can be easily handled and constructed without the use of heavy machinery. Hence, the construction duration of the EC Geoblock gravity retaining wall is expeditious. The revolutionary EC Geoblock gravity wall illustrates a paradigm shift in construction, ushering towards an era of urban sustainability. The self-interlocking mechanism of the blocks eliminate the need for mortar or cohesive materials. The simple block shapes of the letter 'E' and 'C' makes casting faster and easier with less room of failure. The reasonably sized blocks can be maneuvered easily by manual labour without the needs of large machinery so the EC Geoblock gravity wall can be constructed in places with limited access. Hence, it incorporates the spirit of SDG 9, promoting sustainable industrialization, fostering innovation and building resilient infrastructure. On the other hand, the spaces in between blocks can be infilled with sustainable granular material, improving drainage ability of the wall while minimizing waste and reducing the environmental footprint. This innovative system creates a stable and sound wall with great cost effectiveness which align with SDG 11 that focus on making cities and communities safe and sustainable. Th ground breaking solution paves the way for a better and more sustainable future.

2. METHODOLOGY

2.1 Project Background

The study area is located at a car service centre at Kawasan Perindustrian MIEL, 43650 Bandar Baru Bangi. The initial design of the retaining wall was a reinforced concrete wall with a length approximate to 36.6m, 2m high and the structure is 3 to 4m away from the monsoon drain. The existing wall was built and completed in 1994. Gravity wall which was constructed with EC Geoblock was proposed as a remedial solution to the problem. The entire project contains three phases which is illustrated in the Figure 1 below. The project begins with design which is then verified with simulation using Geosolve SLOPE program. The Janbu's method: Horizontal Interslice Force of analysis was used to determine the most critical failure surface and the most critical factor safety is 1.887 which satisfied the design requirement.

Figure 1. Project flow chart

2.2 Design of EC GEOBLOCK

Two types of EC Geoblock are used in this study. The shape of the blocks which are "E" and "C" define the name of the block. The C block is half of the E block and both of the dimensions are shown in Figure 2. The blocks are designed to have size that can be carried manually, self-interlocking without mortar and able to form space in unique arrangement that can be infilled with granular material for better drainage ability. EC Geoblocks are made of grade 30 concrete which includes portland cement, sand and water.

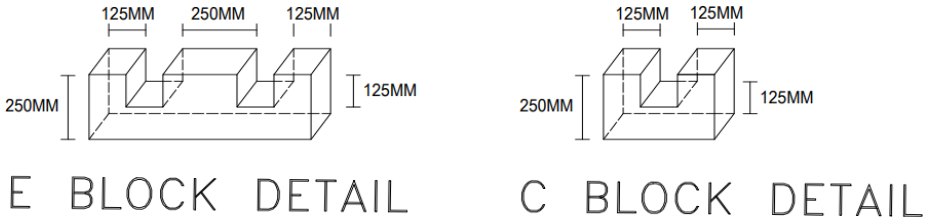

Figure 2. Dimensions of E and C Blocks

2.3 EC Geoblock Gravity Wall

EC Geoblock gravity wall is constructed with interlocking EC Geoblocks. The innovative interlocking design of EC Geoblocks eliminate the need for mortar or adhesive material. The space in between blocks can be backfilled with granular or sustainable fill sourced from site, improving drainage, minimizing the impact to the environment and reducing cost. Figure 3 and Figure 4 illustrates the typical arrangement of EC Geoblock gravity wall. Figure 5 shows the actual cross section of EC Geoblock gravity wall at site.

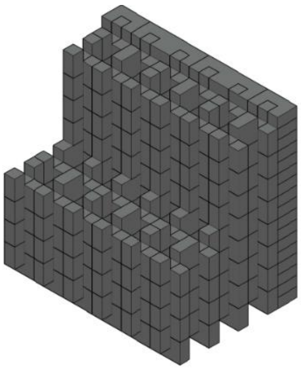

Figure 3. Typical isometric (30°) arrangement of EC Geoblock gravity retaining wall

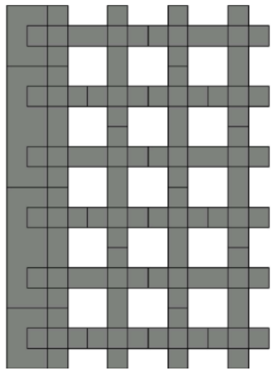

Figure 4. Typical Plan view of EC Geoblock gravity retaining wall

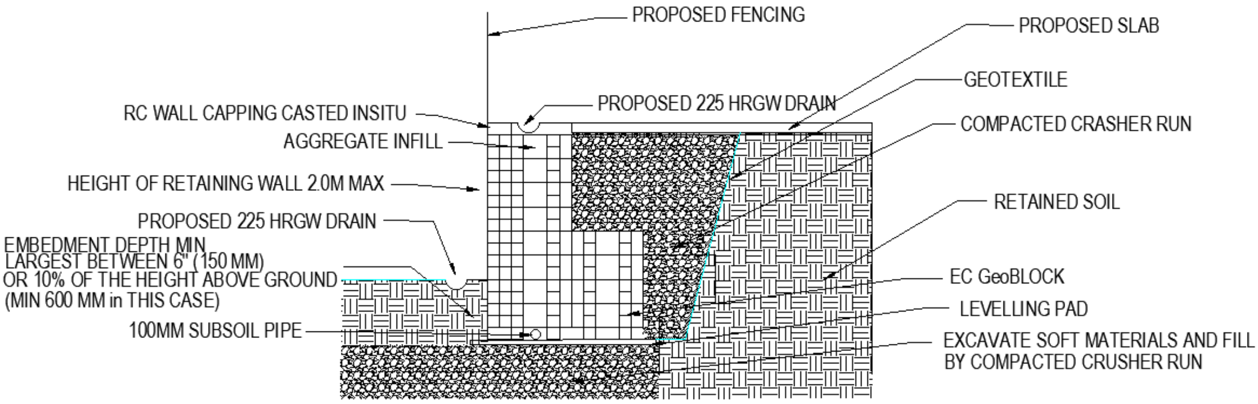

Figure 5. Section views of EC Geoblock gravity retaining wall at actual site

2.4 Construction Phases

The remedial process begins with clearing the site where the failed wall possibly due to heavy rainfall is removed from the working area. The RC retaining wall was built in 1994 and failed on 10th November 2021. The RC retaining wall was believe to be experiencing overturning and bearing failure (Figure 6) as the generation of pore water pressure from rainfall and car wash activities can exert lateral pressure towards the wall. Simultaneously, the increase in pore water pressure causes reduction in the effective stress as both components make up the total stress. Decrease in effective stress lead to lower shear strength which diminish the bearing capacity of the soil and lower the factor of safety [19] resulting in bearing failure.

Figure 6. RC retaining wall failure

Before construction commence, site investigation consists of 8 mackintosh probes and test pit were carried out to determine the sub-soil condition of the study area. Moreover, relevant design survey plan and building layout were also obtained. The initial stage of the process involves the clearance of debris from the collapsed area. Subsequently, the ground is levelled, and granular material is filled (Figure 7) and compacted to form a flat base (Figure 8).

Figure 7. Filling of granular fill

Figure 8. Compacting of granular fill

The in-situ California Bearing Ratio (CBR) test is a type of geotechnical test to determine the bearing capacity of the soil. The test procedure involves gradually penetrating a standardized plunger into the soil where required force for specific penetration is measured. The In-situ CBR value can be obtained by comparing the measure force to the required force to penetrate a standard crushed stone sample. A high CBR value indicates the soil has strong load bearing capacity. Therefore, the result of CBR test of two selected points which achieved 97.7% and 91% (Figure 9) are deemed satisfactory for wall construction. After the test, casting of levelling pad with thickness equal to 150mm is carried out to provide a flat surface for the placing of EC Geoblock (Figure 10).

Figure 9. In-Situ CBR test

Figure 10. Casting of levelling pad

The alignment is checked with theodolite to ensure the pad is flat before laying of EC Geoblock (Figure 11). EC Geoblocks are placed according to the approved drawing with manual labour efficiently (Figure 12). The alignment of each layer of EC Geoblock are checked with spirit level to ensure the structure is stable.

Figure 11. Alignment checking

Figure 12. Laying of EC Geoblock

Subsoil pipe is installed at the bottom of the wall. This step ensures the surface runoff and water can be effectively diverted from the granular filled in between the blocks. After placing of subsoil pipe, the process of laying EC Geoblock continue (Figure 13) without interruption, reducing the risk of building up pore water pressure that can cause potential damage to the wall.

Figure 13. Subsoil pipe installation and laying of EC Geoblock

The selection of suitable backfill material is vital for the longevity and stability for many structures especially retaining wall as it directly affects the effectiveness of wall to resist lateral deflection and settlement. Granular material is often a great and popular choice for backfill material due to its great draining ability and the ease of compaction to mitigate future risk of erosion. Hence, crusher run which is a type of granular material is chosen as the backfill material for the remedial work. Backfill (Figure 14) and compacting of crusher run (Figure 15) are done when each layer of EC Geoblock is laid to ensure the fill were well compacted. Subsequently the rubble wall is constructed at the end of the wall which connect seamlessly with the EC Geoblock gravity wall (Figure 16).

Figure 14. Backfill crusher run

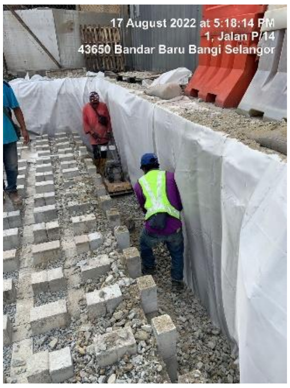

Figure 15. Compact crusher run

Figure 16. Construction of rubble wall

Broken slabs were cut and used as backfill material to reduce wastage. The construction of EC Geoblock gravity retaining wall were completed from 6th August 2022 to 23rd August 2022. In other words, the entire process of remedial work ends within a month which proved its worth in emergency remedial work. The end result is aesthetically pleasing and the facing of the wall have abundant design potential (Figure 17).

Figure 17. EC Geoblock gravity retaining wall

3. RESULTS AND DISCUSSION

The entire construction process ended within a month's time and the quick completion is due to easy transport and handling from the light weight block. The time taken to place the blocks is also reduce as no mortar is used in the arranging the blocks. The drainage performance of the EC Geoblock gravity wall is observed to be excellent due to the granular fill between blocks.

Figure 18. Reference points

Several reference points are selected to monitor the horizontal displacement of the wall. Horizontal displacements were measured at six points distributed across the wall to assess potential horizontal wall movement as shown in Figure 18 were taken after backfilling. The allowable displacement according to BS 8002 is 0.5% of the wall's height which in this case is around 10mm which is above the maximum displacement recorded in site. Hence, it can be proved that the EC Geoblock wall is safe and feasible. Table 1 has summarized the displacement of the six reference points.

Table 1. The deflection of the EC GeoBlock wall after backfilling

Reference Point	Displacement (mm)
Point 1	3
Point 2	4
Point 3	2
Point 4	3
Point 5	6
Point 6	5

4. CONCLUSION

The simple but innovative EC Geoblock present a revolutionized solution as gravity wall to retain the earth. Its ease of transport and handling and expeditious installation coupled with effective drainage performance making it a trustable and efficient choice. The average low wall displacement of 4mm which is less than 0.5% of the wall height show the good performance of retaining the soil. In addition, the aesthetic appeal of the block can be further improved with various design and patterns.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Y. H. Loke: Conceptualization, Methodology, Writing- Original draft preparation.

N. N. Nik Daud: Supervision, Writing- Reviewing and Editing.

N. A. Bakar.: Writing- Reviewing and Editing.

DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are included within the article.

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