ENGINEERING RESEARCH JOURNAL (ERJ)
Vol. 1, No. 46 October 2020, pp.224-236
Journal Homepage: erj.bu.edu.eg

Geo-Foam, Lightweight Backfill impact on Urban and Landscaping Applications.

Walid Abdul-hady Shoura[1] Ayman M. Zakaria Eraqi[2]

[1]Lecturer, Department of Architecture.
[2]College of Fine Arts, Minya University, Minya, Egypt.

Abstract

In the last two decades, there has been a great revolution in materials science and technology. Suitable materials make modern life easier, safer, and more comfortable. Starting from the flexible polymers in the chair you're sitting on, the metal ball-point pen you're properly using and the modern concrete that constructed the building you live or work in, to the materials that make up the urban image, including spaces and its landscape design elements, all these items are created and shaped by materials science and technology. They are engineered to give us the greatest possible control on projects and applications, from design to detailed drawings including timelines, economic costs, and ultimately control over quality results.

Accordingly, research determined one creative material which represents an innovative concept that can efficiently solve many of the urban and landscape projects problems, focused on "structural fill challenges*", which could cause negative impact on projects management major factors (Time, cost, and quality), as well as exploring how smart materials technology systems can be applied to that challenge, and proving how it helps in solving such problems, by studying specific cases from different countries. On the other hand, research showed that new materials and technology systems can create the imagination of landscape architects with less structural boundaries, for the sake of achieving user needs, and the aesthetic values of the city image.

Keywords: Technology, Landscape design, Geo foam lightweight backfill, Project management main factors.

Introduction

Although arguing that old methods are the best, the truth is that the revolution of the new technology and materials system in the building industry has made life safer and easier. Nowadays, there is no way to work in any field without new technologies[1]. These new materials and technology systems allow urban and landscape designers to explore several new ideas of expression and find new spatial forms with aesthetic and functional aspects of created spaces.[2] Also, it could help better realize their design creativity needs, as they can make daring designs in terms of improved strength, flexibility, and structure design durability. This structure issue is one of the great challenges to the designers, especially urban and landscape designers. One of these structure problems is "structural fill challenges" which impacts project management major factors (least quality, with high cost, and longest time).[3] But using "Geo-Foam" lightweight backfill new material could efficiently solve many of urban and landscape projects problems, regarding these structure design challenges.[4]

The Statement of the Problem

Lack of awareness and knowledge of new materials technology systems has a negative impact on projects management major factors (Time, cost, and quality).[5]

Objective

Achieving landscape and urban design projects cost, time, and quality project management efficiency in Egypt.

Material and Method

The methodology consists of a strategy combining qualitative and action research methods, while its material is a survey study to be fulfilled via questionnaire.

1. Landscape architecture design definition

There are a lot of varied definitions regards this field, but for this research direction generally Landscape architecture design main valued goal is to create and protect the beauty in the human settlements,[6] According "ASLA" definition: "*Landscape field is*

* structural fill challenge definition mean`s: the structure problems caused by the overweight of soil, above infra-structure, roofs and basement slabs, for slope stabilization, embankments, and retaining walls structures ……..etc., Ref: https://www.afsinc.org/structural-fill, American Foundry society.

*including groups of activities dealing with outdoor spaces, with preserving all natural sources, environment, and creates safe and useful atmosphere**".Thus, landscaping is the result of multidisciplinary cooperation coming from the fusion of art and science, depending on the practical and theoretical experience[7]. To be able to meet this dilemma, it has to be subjected to a constant transformation process, to keep up with variable communities tastes, identity and of course their needs, as well as rapidly changing technology growing with the progress of civilization.

2. Defining Technology

Technology is a term which has just joined the modern literature in a variety of fields. Thus, there is a variety of definitions for the same. For instance, the encyclopedia associated with McGraw Hill generally defined technology as "the science and systematic operation in relation to industrial issues which can be generalized to other non-industrial fields."[8] The idea is that technology emerges out of science. Scientists propose principles and laws, test them by experiment, and then engineers and inventors apply their findings to construct new technologies,[9] within sum technology is known as the key for altering natural assets into work and services.[5] The aspects of technology research are split into three items:

- Information: describes the part associated with technology data that may be gathered as well as written.
- Skill: originates from people who possess the bodily ability and also the mental capability to do a particular task. Skill itself is actually divided in to mental as well as physical abilities
- Foundation: is also an important technology component that the other system aspects of technology operate to ensure technology would work as an ***incorporated and single system. Foundation and information components constitute the technologies science that's further split into procedural as well as explanatory components[/].[8]*** Simply, technology has made our lives easier, faster, better

3. Between Technology and Landscape Architecture

Landscaping is a discipline that running in parallel with new materials and technology systems. This means that a number of specialists could be exploring the opportunities of using new materials technologies and, thus, outlining the prospects for the development of the new materials becomes motivated to carry out a wide range of ideas. In basic terms, these new materials and technology can do the following:

- Achieve human needs in an easy and comfortable way, with less time, effort, and cost with best possible quality.
- Produce outdoor places that are ecologically appropriate, functionally successful and aesthetically pleasing.
- Solve existing urban and landscape problems, and predict the upcoming ones to solve them.
- Shape the elements of hardscape and develop softscape items.
- Help softscape (planting elements) to be healthier and create several items who can resist the climate and soil problems.
- Create new technical and aesthetic values.
- Provide practical application between new and traditional technology systems.
- Modify and add value to the landscape architect's workshop.[10]

The results of these studies have become a key to landscape architecture field, giving its creators an up-to-date and dependable technical workshop. Accordingly, known and well-established construction technology knowledge, including updated ones, puts landscape architecture in a powerful and responsible and professional status.[11] As well as the proper space design, the landscape architecture must construct the well-built framework structure with suitable outdoor open spaces which require lots of new abilities and understanding, beside the use of the correct tools, materials and technologies systems.[12]

4. Structure fill challenges

Defined as the structural problems caused by the overweight of soil (backfill), above infra-structure, roofs and basement slabs, or for slope stabilization, embankments, and retaining walls structures,[13] so conventional backfill materials are very heavy and becoming costly. This great challenge regarding any backfill on structure is the weight of that material and its behavior. Also, this problem puts a lot of challenge on project engineers, and on major project management factors (cost, time and quality), Thus used lightweight* back fill is most, it has long been recognized for reducing mass to reduce the gravitational loads, which in turn reduce the bearing capacity loads and settlement.[14]

For any project requiring backfill, lot of materials alternatives may be found to consider. However, due to a lack of knowledge with these alternatives (especially the new materials), engineers wouldn't consider them. This research has been written to make awareness for the new materials and technology systems and determine what the appropriate materials are available for use as a backfill in construction; especially in areas where a lightweight fill is most significant.[15]

5. Lightweight Backfill Materials Alternatives

Various lightweight materials fills have been used for many years around the world using the following alternatives: natural materials, organic-origin materials,

* ASLA , The American Society of Landscape Architects, https://www.asla.org/aboutlandscapearchitecture.aspx .

* lightweight fill is : any material used to replace a heavier in situ soil to reduce the load on subgrade soils, or structure slap or wall, Ref: Hema Kumar Illuri Ph.D, Andreas Nataatmadja Ph.D1, sustainable backfill materials made of clay and recycled EPS..

industrial waste materials, and recycled/secondary materials,[15, 16] as following:

- Natural materials:
  1. Natural lightweight aggregate (pumice) (it is not available in Egypt in large quantities).[17]
  2. Light Weight Clay Aggregate, 6N granular backfill.[18]
  3. Lightweight expanded clay, shale and slate "ash-rock" aggregate generated from 100% coal ash,[14, 19] (all expanded soils are not recommended as they can cause significant structural damage; especially for retaining walls).[16]
- Organic origin materials, these materials are inexpensive and light. Although many of their qualities are good for a fill material, but on the other-hand in many cases when placed above the permanent water-tables are highly biodegradable. And, toxins may leak from wood to groundwater table. A danger of fire also exists during the construction, (but it is not available in Egypt in quantities).[18][
  1. Chipped bark residue (dried trees trunks cover) , dried peat, (dried plants),[14]
  2. Saw-dust, and wood-chips and chunks from the timber industry.[15]
- Industrial waste materials:
  1. Fly ash, slag, cinders[14] (it is not available in Egypt in quantities).
- Recycled/secondary materials:
  1. Shredded tires, it is an inexpensive product. The use of tires below the water level may causes toxins to leak from wood to groundwater table.[15, 20]
  2. Cellular (foamed) concrete, Consists of Portland cement, silica, lime-silica blended together with homogeneous void or structured cell, by gas-forming chemicals or foaming agents and foam.[21]
  3. Expanded polystyrene (EPS or Geofoam): it is a formed heavy duty Styrofoam that is by far the lightest lightweight fill materials ever compared to other materials alternatives. It is non-biodegradable, easy to place in site. EPS is used widely in Europe and the USA.[15][Despite EPS material is more expensive than others alternatives, there are a lot of studies which proved that it was selected as the most economical solution for material savings, time and effort consumption, site workability and better quality.[18, 22] EU countries and USA states have evaluated that use of EPS Geofoam is the best as a lightweight fill alternative material.[14, 23][.

Based on that, research determined the Geofoam lightweight fill as an innovated material which can efficiently solve several urban and landscape architecture problems regarding structural fill challenges. Also, it could be utilized for hard concrete shaping and land forming.

6. Geofoam Description

Geofoam is a lightweight material expanded polystyrene fill "EPS", used as a geotechnical material since 1972 in "Norway".[18] It is approximately 1% the weight of soil and less than 10% the weight of other fill materials, very easy to handle on site, without need for special equipment, and is not affected by weather conditions. Also, it can be easily shaped and cut on site.[22]

6.1 Applications & use in urban and landscape architecture fields

Geofoam is actually a multi-functional material, used in several applications with several advantages, like retaining walls, slope stabilization, as well as being used in airfields, train track techniques, highways, beneath tanks and sports arenas and landform applications, and retaining walls backfill. This might enable technical engineers, landscape designers, and contractors to apply it in a wide range of solutions, to achieve project goals, with extraordinary flexibility as well as strength. it offers innovative options and safety.[23]

6.1.1 Airport runway/taxiway and Road construction for poor soils

New roads developing often takes time; requiring building over soft soils or even loose ones that cannot tolerate extra loads. Geofoam can be used to replace all heavy fill materials to prevent extra loading on adjacent structures and soils. It is able to support effectively all traffic loads on runways and highways. Also, it can save Construction time because it is easy to handle without any special equipment.[24] Typical road fill, from bottom to top description, is as follows:

A layer of sand base is compacted to provide a level and free draining construction surface. A geofoam layer is set up to the needed height. A separator layer may be placed between the top of the Geofoam and the overlying pavement. Road base gravel and concrete or asphalt pavement driving surface, is subsequently constructed on the of top the separation layer,[25, 26] Fig (1, 2, 3, 4).

Fig 1 road section with geofome

Fig 2 New Orleans Airport Kenner, Louisiana, USA runway rehabilitation

Fig 3 Borman Expressway USA

Fig 4 Alaska Way Viaduct in Seattle, washington, USA

6.1.2 Road Widening

Roads often need to be widened for traffic reasons. This situation results in the need to add fill to roadway. This is often an expensive as well as time-consuming process when the soils next to the current roadway aren't appropriate to support the loads of the traffic since the resulting settlement affects the current roadway. Utilizing Geofoam may negate the requirements for compaction fill up testing,[27] reduces time of construction and reduces impact on the existing road. The actual high resistance of Geofoam could withstand the actual induced traffic forces without causing any kind of loading from the underlying soil or surrounding fill. The biggest Geofoam project in the USA was the widening of I-15 roads in Salt Lake Town, Utah, from 1997 to 2001, with around 100, 000 m^3 of Geofoam blocks,[4] Fig (5).

Fig 5, Road widening, Gary, Indiana,USA

6.1.3 Bridge supports

There are a lot of advantages to using EPS Geofoam to construct bridge supports approach fills. Geofoam can for its high compressive resistance, safely support highway loading without soils over-stressed. The use of Geofoam reduces the cost of construction for the bridge approach slab and its long-term maintenance. Also, when compared to traditional fills, Geofoam significantly reduced the forces on supporting walls, other retaining structures and foundation, because the transmitted force is proportional to the weight of the backfill, if this weight is reduced, as with Geofoam backfill case.[19] The King County Road Services Division in Washington State undertook a project to reconstruct York Bridge over the Sammamish River with Geofoam,[28] Fig (6).

6.1.4 Bridge under backfill

EPS Geofoam can be used to support bridges when designed. In cases when the existing bridge cannot not structurally carry the required loads, Geofoam fill help support the transfer load and span safely to the foundation or soil.[19], Fig (7).

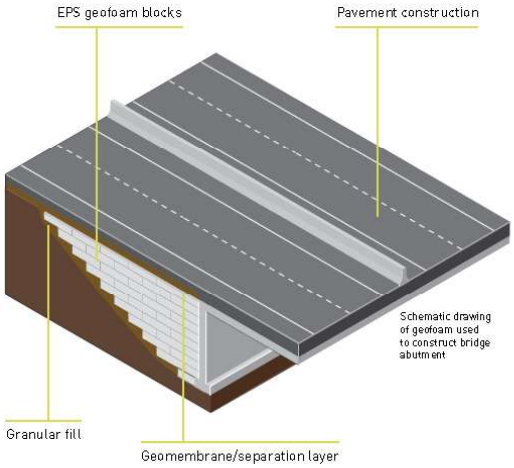


Fig 6 bridge section treated with geofome support

Fig 7 St. Louis, Missouri under an active bridge along Tucker Boulevard, USA

6.1.5 Compensating Foundation

EPS Geofoam can be used as the compensating foundation to lessen the fill on earth and reduce building negotiation. Existing dirt is excavated to lessen the internal applied load towards the soil through the new framework. If the quantity of soil excavated equals the entire weight or even stress applied through the new framework, the foundation is known as “floating” or even “fully paying,[4, 19] Fig (8).

Fig 8 reduce the load on underlying compressible soils for marina

6.1.6 Rail embankment

EPS Geofoam can be used to construct railway embankments that do not overload the existing soils. As a fill material, it is strong enough to support railway loads. It used in the expansion of the Utah Transit Authority (UTA) TRAX light-rail system near Salt Lake City, Utah, USA,[27] Fig (9,10).

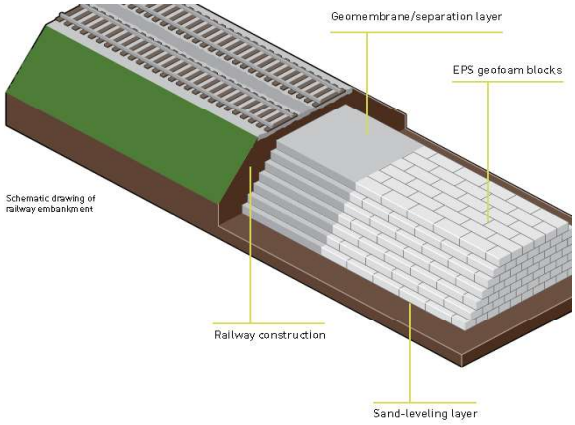


Fig 9 section for rail embarkmet with geofome

Fig 10 rail embarkmet with geofome USA

6.1.7 Vegetative green roofs and Landscaping

EPS Geofoam can be used to create topography without adding any load to underlying services and structures. Some examples of this application include creating urban building roof gardens, underground parking garages or any landscaping over structural slabs,[24, 27] Fig (11).

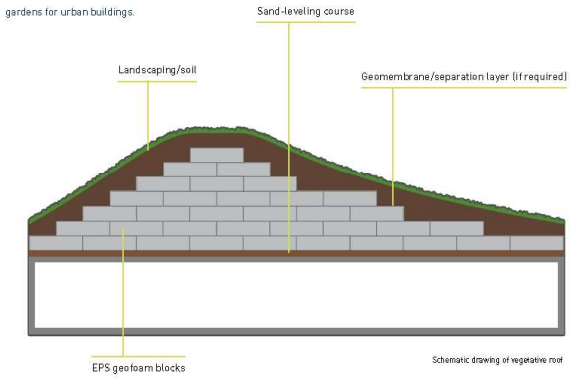


Fig 11 geofome in the construction phase in millennium park Chicago, USA.

6.1.8 Buried and Retaining wall backfill

EPS Geofoam may be used as backfill for buried structure and keeping walls to decrease the pressures on the structure. Since the horizontal pressure acts on a retaining-wall to backfill loads, the utilization of EPS Geofoam backfill also limits earthquakes horizontal forces on structure. And with adding proper drains for retaining-walls applications will avoid water pressure and uplift forces from sites contained loose soil as well as shallow groundwater,[22, 25] Fig (12).

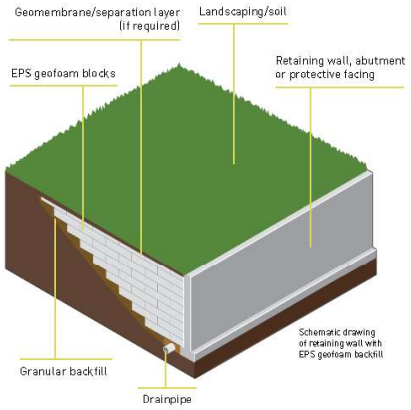


Fig 12 Geofoam retaining wall backfill for West Virginia, University student housing project, USA.

6.1.9 Slope stabilization

Unstable slopes can be treated by removing a volume of existing soil and replacing it with Geofoam lightweight material, thus improving its stability with unloading the landslide top. With this method, a factor of safety can be achieved against future sliding, with a timeless and costless way,[22, 29] Fig (13).

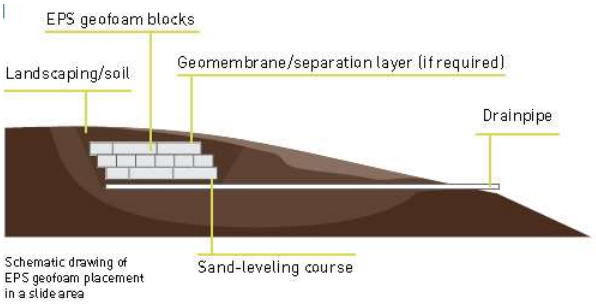


Fig 13 Repair unstable slopes along County Highway Duncan, British Columbia, Canada

6.1.10 Levees (Dams)

Levees are made on compressible alluvial earth along streams. These water saturated soils settle with time due to primary as well as secondary compression. This ongoing settlement leads to the levee needing to be frequently raised to provide the preferred flood protection. Levees are often raised along with conventional fill to return the levee back to its designed level. The additional weight in the levee increasing levels causes extra settlement and also the cycle associated with settlement as well as rising proceeds. Geofoam could be easily installed to create the required volume to come back the levee in order to its designed level after add protective soil cover should be added over the Geofoam,[4, 24] Fig (14).

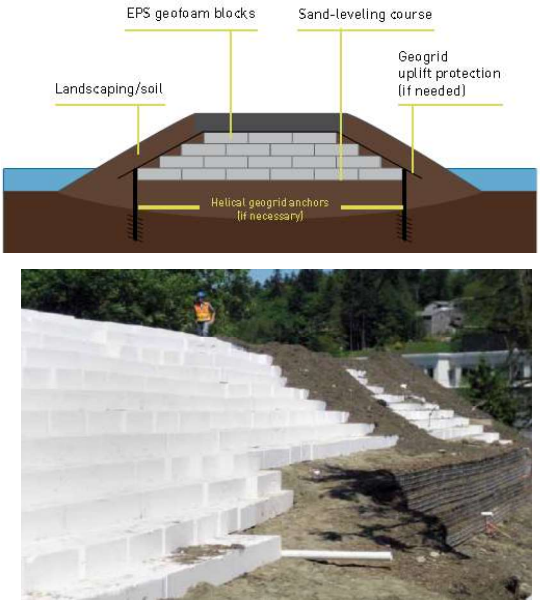


Fig 14 North Creek levee, Bothell, Washington. USA

6.1.11 Special applications (noise barriers, theater steps…..)

This section describes some applications of EPS Geofoam in construction such as noise or visual barriers, expansive soils, earthquake mitigation, permafrost and rock fall protection, and even indoor applications such as theaters steps,[22] Fig (15,16).

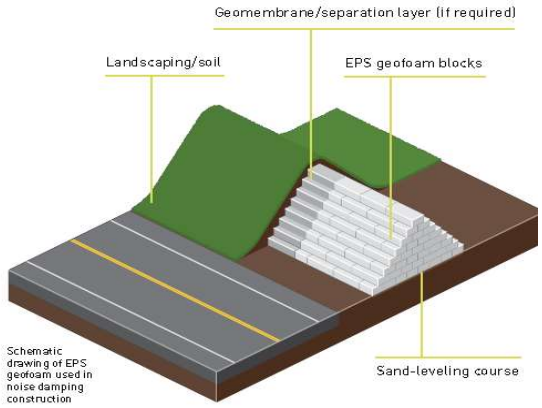


Fig 15 section in noise damp with geofome

Fig 16 Theaters (indoor and outdoor) steps

7. Material Design precautions

These types of design factors include engineering properties as well as construction factors. This part represents the actual precautions that must definitely be followed[27].

EPS Strength	The customer can pick the specific needed for loading whilst reducing cost by using low strength for less loads.	
EPS Protection	Chemical Exposure	It could be damaged when exposed to certain hydrocarbons and needs resistant geo-membranes protection like polyethylene, Ethylene Interpolymer ……etc.
	Fire	Appropriate precautions ought to be implemented on site regarding flame. It is actually flame retardant; this retardant can avoid the early phases of fire development.
	UV light	It is susceptible to ultra violet light if exposed to sunlight for a long time. Just Surface Color effect brought on (yellow colored dust).
	Wind	Wind speed to be monitored on site to avoid blocks moving.
	Buoyancy	Care should be taken throughout design, construction as well as post-construction to ensure the possible flotation. Sufficient drainage system to be provided prevents water from infiltration and reduces the development of uplift forces.
	Water absorption	The actual closed-cell of EPS allows limited water absorption. When utilized in well-drained settings, no alter in EPS weight occurs with time.

8. EPS Geofoam Advantages

Light weight	It is stated in various weights which typically vary from about 11.2 to 45.7 Kg/m3; meaning small dead-load.
Easy Handling	No special equipment is needed when using its Blocks. It could be carried and set by workers, as well as being easily cut utilizing a hot-wire or hands or chain saw.
Construction time	It assists projects time preserving. The speed and ease with which construction may be carried out, reduce site power and traffic.
Construction cost	It decreases loads on structures, resulting in less construction cost; thus enabling economical project design.
Stability	It is recognized as the permanent material when properly specified as well as installed.
Insulation	It is an efficient thermal insulator (if needed). It has been used many years as insulation for building applications.
Sustainability	It could be recycled as well as reused in several composite applications; for example lightweight concrete, plastic wood, etc., fewer trucks with little loads necessary for transportation; thus reducing pollution.

9. EPS Geofoam types and technical specifications

EPS is available in different types. Thorough understanding of the EPS type being used on project is essential. Types and technical specifications are asin the following tables.[28]

Type	EPS12	EPS15	EPS19	EPS22	EPS29	EPS39	EPS46
Density min. Kg/m3	11.2	14.4	18.4	21.6	28.8	38.4	45.7
Compressive resistance min. KPa (psi) 1%	15 (2.2)	25 (3.6)	40 (5.8)	50 (7.3)	75 (10.9)	103 (15.0)	128 (18.6)
Compressive resistance min. KPa (psi) 5%	35 (5.1)	55 (8. 0)	90(13.1)	115(16.7)	170 (27.7)	241 (35.0)	300 (43.5)
Compressive resistance min. KPa (psi) 10%	40(5.8)	70(10.2)	110(16.0)	135(19.6)	200(29.0)	276(40.0)	345(50.0)
Flexural strength min. KPa (psi)	69(10.0)	172(25.0)	207(30.0)	240(35.0)	345(50.0)	414(60.0)	517(75.0)
Oxygen index min. volume %	24.0	24.0	24.0	24.0	24.0	24.0	24.0

Table 01 Geofoam technical and specs

ESP is resistance to :	**Chemicals that may damage ESP**	
• Alkalis	• Hydrocarbons	• Concentrated acids
• Dilute inorganic acids	• Chlorinated Hydrocarbons	• Vegetables oils
• Gypsum plaster	• Organic solvents	• paraffin
• Most alcohols	• Ketones	• Animal fats and oils
• Silicon oil	• ethers	
• Solvent – free bitumen	• Esters	

Table02 Technical propeties and specs of Geofoam

10. Case study in Egypt

"The polygon Westown business park" project owned by "SODIC development" in Elshikh Zaid City, 6th october city, Egypt, the project is a complex of 11 buildings and an underground parking beneath the whole project area, it extends over 70,000 m^2 with 29,000 m^2 landscape net area. Construction started in 2010 and ended in 2015. Consultants were:

- EHAF, main consultant.
- Wikinson Eyre. Architects, Lodon office, Designer.
- COSMOS-E, structure consultant.
- Earth JV. Purescape, Landscape consultant, Fig (17, 18).

Fig (17) "The Polygon West-own business park "master plan and project conceptual perspectives 01

The project landscape constraint is that the underground parking beneath the project was loaded with more than 50,000 cubic meters of backfill (landscape leveling over structure parking area), palms, big trees and shrubs with huge loads, and hardscape items, too. The project Landscape consultant proposed Foam EPS instead of conventional backfill materials as a great alternative that should make a significant load reduction, which reduces structure cost by an average 30% of total basement slab structure cost, save more than 1 month of time schedule (for above leveling and finishes), and give flexibility to the landscape consultant, Fig (19, 20, 21).

Fig (18) "The Polygon Westown business park"conceptual perspectives

Fig (19) Foam location master Real Master plan

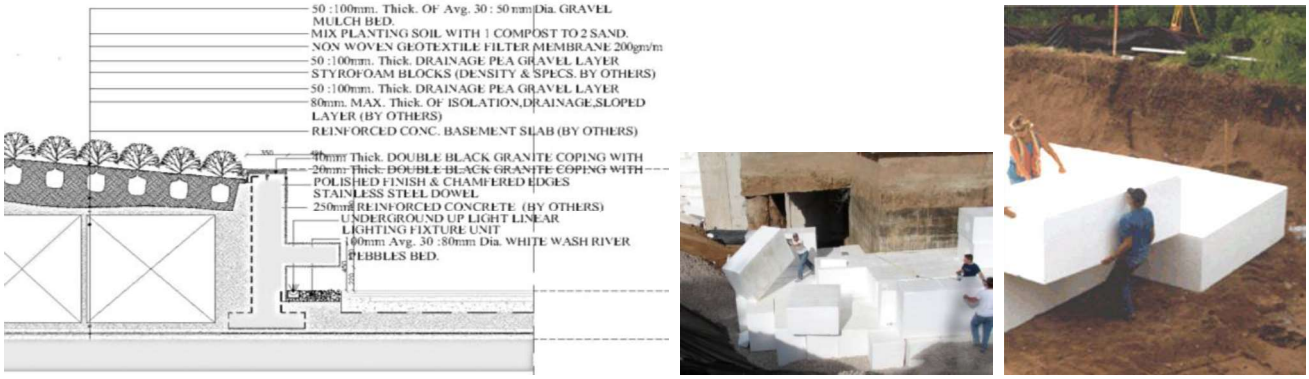


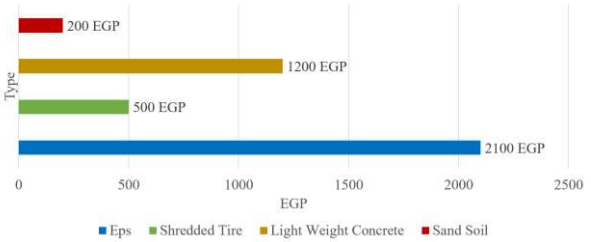
Fig (20) Geo Foam construction document details & real photos foam site implementation

Fig (21) "The Polygon West-own business park" real photos.

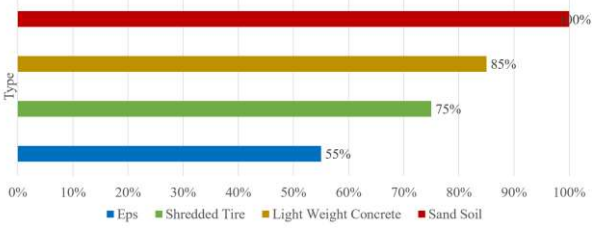
10.1 Backfill materials alternatives comparison

"The polygon Westown Business Park" project Case study analysis: average weight, material direct cost, total Structure cost, Cost analyses conclusion, Co^2 footprint, and construction time rate.

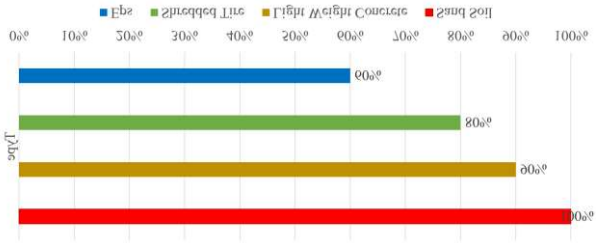
Average materials weight comparison Chart 01



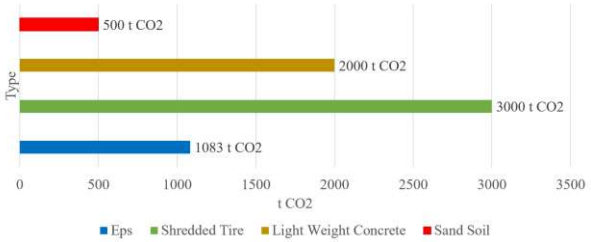
Materials direct cost comparison Chart 02



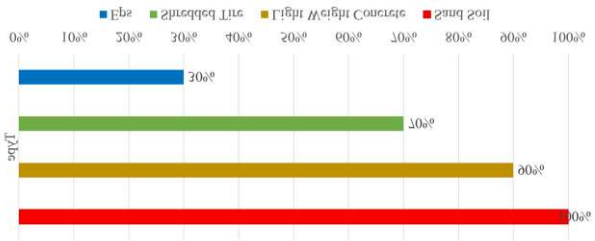
Total structure cost rate comparison Chart 03



Average Cost analyses conclusion Chart 04



Average Co2 footprint for materials comparison Chart 05



Construction time rate comparison Chart 06

11. Results

Through the previous analyses and next questionnaire survey study with Project participants could be monitoring the effect of used Geofoam material in the case study regarding main management factors (Time, cost and quality), as well as design flexibility. The conclusion is as follows, Table (3) :

participants	Position	office	Site	Experience
Sodic owner	top management	**2**	**-**	**+20**
	middle management	**2**	**1**	**+15**
	site coordinators	**-**	**3**	**+7**
EHAF Main consultant	project managers	**1**	**-**	**+20**
	project engineers	**3**	**-**	**+10**
	Structure engineers	**1**	**-**	**+7**
	project managers	**-**	**1**	**+20**
	project supervision		**2**	**+7**
	Structure supervision		**1**	**+10**
COSMOS structure	structure team leader	**1**		**+10**
	structure design team	**3**		**+4**
	structure supervision team		**2**	**+10**
Earth	Landscape team	**3**		**+7**
Purescape landscape	Project manger	**1**		**+20**
	Design team leader	**1**		**+7**
	Landscape Design team	**2**		**+4**
Total questionnaire survey study 30 per.		**20**	**10**	

Table 03 participation of questionnaire survey

1- Do you know anything about Geofoam (EPS) material?

2- Geo foam (EPS) Availability in Egypt

3- How much Light weight?

4- Does it affect the structure design positively?

5- Does it decrease construction cost?

6- Does it increase Design flexibility?

7- Does it affect project Workability positively?

8- Does it decrease the total project cost?

9- Does it decrease Construction time?

10 Does it affect project Quality positively?

- The percentages of the first and second questions indicate that there is a lack of information about the Geofoam (EPS) material as a light weight material.
- In the third question, it becomes clear how much this material is very light.
- Questions no (4, 5) show that this material could reduce loads significantly on structure elements beneath.
- Questions no (6, 7) show that this material could make the project easier and could aid the landscape designer achieve the project optimum solution.
- Questions no (8, 9, 10) show that this material could have a significant influence on management main factors, (less time, less cost, better quality).

12. Discussion and Conclusion

The New technology materials and technology systems, which could potentially solve significantly lots of existing as well as futuristic problems, need to be reexamined and developed. The key point which all of us emphasized in this study is that there are a lot of smart materials and technologies systems that may make the project's cost, time, effort more much less, and allow it to be more efficient. Many of these new materials and systems should be considered by city planner, urban designers as well as landscape architects to discover the needed knowledge as well as tools to remain updated. In addition, using these solutions associated with industrial new building materials could create emblematic and significant blends associated with art as well as science to improve existence and react to the ever-evolving requirements of contemporary life and to expand using outdoor spaces acting not just as a good environmental or even aesthetic worth but might help generate numerous opportunities: creative, economic, positive socialization…etc.

Our study showed this technology could obviously be reproduced in Egypt in order to adapt with industry that could strengthen each Egyptian city urban design and landscape field as well as industry.

New programs need to be created for the new technology and materials, in general, and in landscape architecture design field in particular, in the relevant technical schools (for technicians) and engineering colleges (civil, urban , landscape architecture, architecture ……..) to establish a connection between real life, projects and applied new technologies. On the other hand, the academic life (university to work) need to minimize the great gap and lack of knowledge between the industry and education, and between the academic and professional life in Egypt.

13. References.

[1] 1. Croucher, S., *Globalization and belonging: The politics of identity in a changing world*. 2018: Rowman & Littlefield.

[2] 2. Kuc, S., *Teaching Subject Program of General Building Systems for Curriculum Landscape Architecture at Cracow University of Technology in Kraków, Poland.* 2000.

[3] 3. Smith, J. and F. Magnusson, *The Project Management Triangle: a hidden framework? A qualitative study of ERP implementations in Sweden*. 2015.

[4] 4. Mandal, J.N. *Geosynthetics Engineering: In Theory And Practice. Lecture- 59*
[5] Available from: https://nptel.ac.in/content/storage2/courses/105101143/downloads/Lecture%2059.pdf.
[6] 5. Asadi, M., *A Question on Technology*. 2004, Tehran: Andis cultural institute.
[7] 6. Bohm, A., *Ksztalcenie architektow krajobrazu w Polsce-osiagniecia i niedostatki.* Krajobrazy dziedzictwa narodowego, 2000. **1**: p. 37-39.
[8] 7. De Jonge, J., *Landscape architecture between politics and science: an integrative perspective on landscape planning and design in the network society*. 2009.
[9] 8. Bozeman, B., *Technology transfer and public policy: A review of research and theory.* Research Policy, 2000. **29**(4-5): p. 627-655.
[10] 9. Mitcham, C. and E. Schatzberg, *Defining Technology and the Engineering Sciences*, in *Philosophy of Technology and Engineering Sciences*. 2009, Elsevier. p. 27-63.
[11] 10. Zachariasz, A., *Early development of the profession of landscape architect (Początki kształtowania się zawodu architekta krajobrazu, III Forum Architektury Krajobrazu). Proc. III Forum of Landscape Architecture, New Ideas and Development in Landscape Architecture in Poland,.* Warsaw, 2000: p. 324-333.
[12] 11. Lassus, B., *The landscape approach*. 1998: University of Pennsylvania Press.
[13] 12. Olszewski, A. and Z.J. Pudlowski, *The outcomes and achievements of the Urban Design and Education Programme.* Global J. of Engng. Educ, 2002. **6**(1): p. 7-16.
[14] 13. *American Foundry society*. Available from: https://www.afsinc.org/structural-fill-and-embankment.
[15] 14. Nicholson, P.G., *Soil improvement and ground modification methods*. 2014: Butterworth-Heinemann.
[16] 15. Kohlnhofer, G. *Lightweight Fill Materials for Road Construction*. in *Transportation Research Board Conference Proceedings*. 1995.
[17] 16. Nataatmadja, A. and H. Illuri. *Sustainable backfill materials made of clay and recycled EPS.* in *Proceedings of the 3rd CIB International Conference on Smart and Sustainable Build Environments (SASBE 2009)*. 2009.
[18] 17. Rashad, A.M., *A short manual on natural pumice as a lightweight aggregate.* Journal of Building Engineering, 2019. **25**.
[19] 18. Frydenlund, T.E., et al., *Lightweight filling materials for road construction.* 2002.
[20] 19. Davies, L., J. Bull, and T. Kucki. *Lightweight backfill materials in integral bridge construction*. in *Proceedings of the Institution of Civil Engineers-Bridge Engineering*. 2013. Thomas Telford Ltd.
[21] 20. Cecich, V., et al., *Use of shredded tires as lightweight backfill material for retaining structures.* Waste Management and Research, 1996. **14**(5): p. 433-451.
[22] 21. Averyanov, S., *Analysis of construction experience of using lightweight cellular concrete as a subbase material*. 2018, University of Waterloo.
[23] 22. Hatami, K. and A.F. Witthoeft, *Reduction of backfill earth pressure in reinforced soil walls using geofoam*. 2007.
[24] 23. ASTM, D., *7180–05. Standard guide for use of expanded polystyrene (EPS) geofoam in geotechnical projects.* ASTM, West Conshohocken, Pennsylvania, USA.
[25] 24. Bartlett, S.F. and D. Arellano, *EPS Lightweight Backfill and Landscaping Applications*. 2011, University of Utah.
[26] 25. *The Trusted Lightweight Fill Material* Available from: www.Geofoam.com.
[27] 26. Stark, T.D., et al., *Geofoam applications in the design and construction of highway embankments.* NCHRP web document, 2004. **65**: p. 792.
[28] 27. Coleman, T.A., *POLYSTYRENE FOAM IS COMPETITIVE, LIGHTWEIGHT FILL.* Civil Engineering (New York), 1974. **44**(2): p. 68-69.
[29] 28. *The EPS Industry Alliance info@epscentral.org*. Available from: http://www.epsindustry.org/eps-sustainability/excellence-eps-recycling-award.
[30] 29. Jutkofsky, W., *Geofoam Stabilization of an Embankment Slope, A Case Study of Route 23A in the Town of Jewett, Greene County.* Geotechnical Engineering Bureau, New York State Department of Transportation, Albany, NY, 1998. **42**.