# LIGHT WEIGHT GEOMATERIAL FOR CONSTRUCTION ACTIVITIES IN SRI LANKA - THE PROS AND CONS

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## ABASTRACT

Application of lightweight geomaterial (LGM) in the construction activities has not been widely practiced in Sri Lanka. However, with recent development activities, engineers and planners tend to gradually divert from the traditional construction methods to more modern methods including the application of LGM. Construction of roadways, embankments and foundations in the destabilized hill country and on low bearing capacity marshy lands attracts them to applying LGM as a new alternative. However, conservative engineering practices and high production or transportation costs are key elements, which hinder them yet to use this new material in a massive scale. This paper attempts to demarcate regions, where application of LGM for major construction and remedial activities is possible. It also stresses vigorous market and educational activities needed in this respect. Several case studies with various applications of LGM will be discussed.

**Key Words**: LGM, Sri Lanka, Construction, Education, Engineering, Geomorphology, Marketing, Soils, Slope

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## INTRODUCTION

Application of LGM has not been widely used in Sri Lanka. However, current trend paving the way for engineers and planners to consider LGM as an alternative material where many construction of engineering structures can be completed within the soils having low bearing capacities or lateral movements causing land subsidence. Highlands in the central part of Sri Lanka and marshy lands adjacent to coastal belt need special attention since many new buildings; roads and other infrastructures are coming up (Fig. 1).


Fig.1. Map showing proposed major highways and climatic boundaries.. Central highlands are encompassing Ratnapura, Matale and Badulla

The objective of this paper is to highlight the possibilities of applying LGM at several localities in Sri Lanka. Central highlands where landslide and slope destabilization is prevailing, coastal zones where heavy erosion is active and marshy land within the low land areas where major development activities are going on will be considered as possible areas for application of LGM. Though current prices in the world market for EPS (Expanded Polystyrene) or LGM products and transportation cost to Sri Lanka is high, it is believed that the application of these materials can minimize construction complexities and time consumed. This paper summarizes several regions in Sri Lanka where application of LGM is possible and the ways to overcome constraints put forward by engineers, planners and clients.

## GENERAL GEOLOGY AND GEOMORPHOLOGY OF SRI LANKA

Ninety percent of the country is underlain by Precambrian metamorphic rocks with a thin veneer of sedimentary limestone along the northwestern coastal belt extending from Puttalam to Jaffna (Cooray, 1994). The regolith extended up to 30 m at places in Colombo however, many locations in the central highlands it may exceed up to 100m as some of the drilling records indicated. However, local geology, transported material, weathering, climatic factors, water availability and slopes are responsible for the regolith development of varying thickness. Many lateritic soil profiles are encountered in the wet zone areas, which sometime extended to a depth beyond hundreds of meters. Cooray (1978), Dissanayake (1980), Dahanayake (1982), McCrea, et al. (1989) and Tennekoon (1998) provided general description of laterites and their chemical, physical and engineering properties. Since the material has specific state of gaining strength due to drying, it has been used as a construction material. Morphologically the central part is a dissected mountainous region with highlands, plateaus, deep valleys, exposed ridges and rock out crops with excessive steep slopes at many places, while lower dry lands extending from the center to the northern plains show rolling topography with inselbergs and isolated rock knobs (Vitanage, 1972). In more wetter planes located in the western and southern areas of Sri Lanka have intermittent marshy lands (Senaratne and Dissanayake, 1989) and low bearing soils which sometime being water logged through out the recent geological history. The maximum elevation is 2524m above mean sea level, which is located at the summit of Pidurutalagala in the central highlands of Sri Lanka.

## SLOPE FAILURES IN SRI LANKA

Sri Lanka has experienced large to small-scale slope failure due to gravitational forces aided by heavy rainfall. In the central highlands many roads are experiencing such situations and only local manpower is used to dispose the muck load without taking significant engineering applications to curb the situations. On the other hand the proposed highways in the central highlands such as Kandy-Colombo and Kandy-Nuwara Eliya may require additional attention since these highways are planning to operate under toll system. In Sri Lanka recent activities causing de-stabilization of land mass due to global tectonic plate movements (Sykes, 1970; Eittreim and Ewing, 1972; Munasinghe and Dissanayake, 1982), water bearing reservoir impoundment and various land use activities create situations where micro to macro seismic activities be generated (Jayasena, 1994). These may also assist to activate a number of slope failures evident in many parts of the central highlands of Sri Lanka. In addition extensive construction activities in hilly regions are also susceptible for mass movements that are mainly aided by unattended slope clearance and man made activities.

## APPLICATION OF LGM IN SLOPE PROTECTION

Since the slopes in hilly areas are high with values ranging from 10° to 60° (Premasiri, 1992), the slope de stabilization in a small to large scale is very prominent around many cities in the central highlands. Most of these exposed slopes are unsupported and consists mostly of "insitu" developed or locally transported soil material. They are either lateritic in nature with high amounts of sesquioxides and clay size particles and silt size micaceous particle or sandy to silty loam soils (Moorman and Panabokke, 1961). There exists high risk of local slip failures especially during heavy rains (Dahanayake, 1990; Jayasena, 1994; Malalgoda and Jayasena, 1999). This may eventually propagate endangering the properties both at top and bottom of the slope. Therefore it is of great importance to provide measures to support the freestanding vertical slope before any adverse slope failure is taking place. Once a major slope failure or failure surface is developed it will be an expensive remedial measure to prevent failure.

In many site inspections revealed that the primary need to stabilize the slope is by simple external means. Figure 2 shows stabilization of small earth slip in a hilly region by an earth retaining structure. Soil nailing coupled with LGM mixed fill drain in the space between earth retaining structure and the slope is employed in order to arrest the active landslip. Since the client has requested to use the space for a usable purpose, the original design was changed to the present one. In order to minimize the deformation due to the fill we adopted EPS beads and soil, which could minimize the weight and improve the draining (Fig. 3). The methods to be adopted shall make least disturbance to the soils or soil profile within the slopes and earth retaining structure. Seed and Duncan (1983), Broms (1971), Ingold (1979) and Kulathilake (1998) discuss many case studies and provide numerical solutions to discuss the process, compaction, loading and unloading of such structures. In the absence of proper geotechnical data I propose the application of LGM at the base to stabilize the slopes provided that the engineer and the consultant should adopt those after a detailed design.

Fig. 2. Photograph showing soil nailing through a simple retaining structure. The structure supports the earth slip over peaty clay soil to the right of the photo. Weep holes drains excess water in the disturbed soil mass

## APPLICATION OF LGM AS FILTER MATERIAL

Modification of filter material to cope with the excessive groundwater at the base of slopes and slopes associated with large earthfills can be constructed using EPS beads. Several sizes are available in Sri Lanka however; the strength is to be improved to cope with the anticipated lateral force (Table 1 and 2). The diameters of the beads are ranging from 2 cm to 8 cm with several intermediate sizes. The beads can be placed with cubic or rhombohedral arrangement to obtain known porosity values such as 47.64% or 25.96% respectively. On the other hand just by using two different sizes packing in a cubic system can get a lower value of 12.5 % (Graton and Fraser, 1935). The construction should be completed accordingly to pave the proper passages to groundwater outflow and also to make the structure intact. Instead of rock filled Gabion structures a similar system can be adopted with a less weight. On the other hand concreting the base of structure providing with spaces filled by EPS or LGM can be adopted as for a simple drain in one hand and to control the lateral and vertical pressure over the structure by the soil mass. The other possibility is to construct LGM such as coir, coir dust or peat filled concrete blocks, which could be used as to cope with the above activities so that handling, and longevity can be maintained.

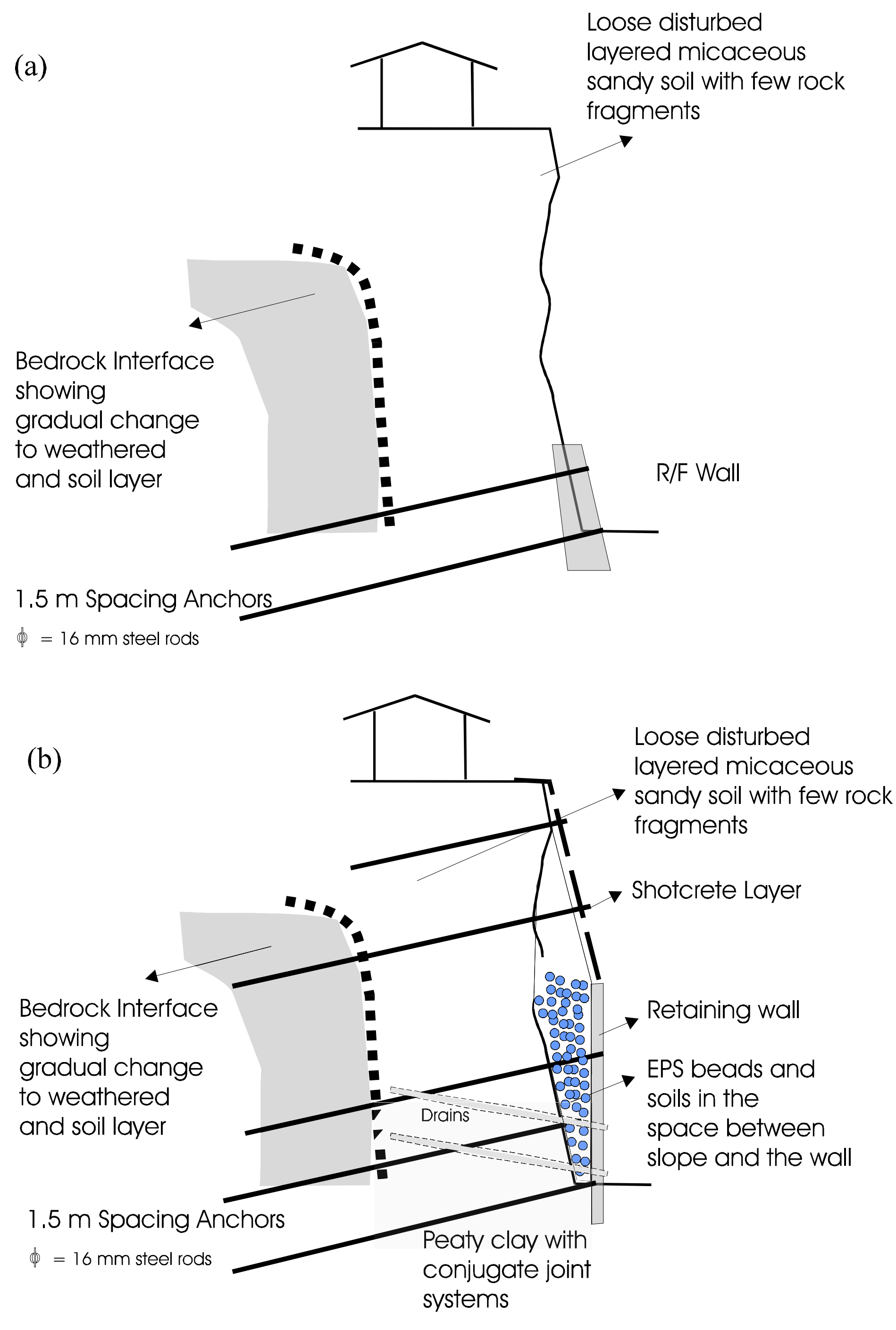


Fig. 3. Details of the retaining structure as shown in the figure 2. (a). Original proposal based on simple reinforced wall and anchors, (b). Earth pressure reduction by filling EPS beads and soil in the space between slope and the retaining structure.

## APPLICATION OF LGM AS DRAIN MATERIAL

In many engineering and environmental activities, excess water drainage is needed. For instance as an erosion control measure along steep slopes retarded drainage has to be adopted. The LGM application in this regard is also expected in the future.

Drainage as a method of slope stabilization can be very effective, but as a long term solution it suffers greatly because the drains must be maintained if they are to continue to function. Drains can do three things. They can control the movement of surface water, and through their influence on the hydraulic boundary conditions of the seepage regime in a slope, bring about the desired reduction in pore water pressure at depth. Such drains are shallow and they are the easiest to maintain, but the ones most likely to fall rapidly into disrepair. Deep drains act to modify the seepage pattern within the soil or rock mass (Bromhead, 1992).

Shallow drains normally take the form of lined or unlined ditches. They may alternatively be shallow gravel-filled trenches. The disadvantage of using gravel is that it takes intensive labor to clean it during maintenance program. However by applying EPS beads with a layer of gravel in order to maintain the proper retaining may control such situations. Ditches are perhaps the most difficult form of drain to keep operational: if the mean discharge is too high, they scour out; if it is too low, they become blocked by weeds. Sometimes they are lined with concrete, or with slabs, the latter to resist scour. This is expensive, and can easily be disrupted should small movements take place. Ditches have the advantage that short duration; high discharges can usually be accommodated, because of the large section of channel available. At the outfall end, they may need substantial works to take the discharge together with materials swept down by the flow.

A use for open ditches in natural slopes is to carry away discharge from springs, or to lower the maximum level of landslip ponds, or to re-route streams. Gravel filled trench drains are used to intercept run-off as well as forming the shallowest of the categories of 'deep' drains. They must then be open at the top and the upper layers of drainage material need to be protected by a filter from the ingress of fines from the catchment, at least until vegetation cover has become established.

This is one such area where LGM can be applicable. However, the design and the construction should be overcome the said problem as discussed in the above. The application of removable EPS beads may sometime useful for the maintenance of shallow drains. As an erosion control measure these beads can be used with a known porosity to entrap the sediment discharge due to overland and channel flow.

## APPLICATION OF LGM IN EMBANKMENT CONSTRUCTION

Embankments constructed of freely draining granular materials need only small factors of safety against shallow slope movements. They usually operate quite effectively without internal drainage layers but may benefit from the inclusion of soil reinforcement to prevent lateral strains on soft foundations. Embankments for existing roads, railway structures and proposed major highways have gained attention by local engineers and government authorities. The soils in the highlands are usually sesquioxides rich clayey sand of laterite and bauxites, which may probably cause little effect due to pore water pressure. If filling or excavation is needed, EPS material can make or expand the extent of the area and reduce the adverse conditions due to pore water pressure and local hydraulic conditions. Local research of applying LGM in this area is still at an infant stage, however, with proper support both from the government agencies and private participation, a suitable designs respective in each case could be implemented.

## APPLICATION OF LGM IN FOUNDATIONS

Differential settlement of structures built in marshy lands and soft soils has caused many problems for buildings and other infrastructures. Expansive soils and foundation heave as a result may also caused settlement problems in many local situations. Herath (1973) observed montmorillonite clay in the soil profiles of many dry areas of Sri Lanka, which is considered as expansive and causing heave. Therefore, application of LGM in foundation problems is to be considered in the construction activities. Especially when uniform-bearing layers either within the earth or on the surface have to be developed. Employing layers of effective and homogeneous LGM material can convert many marshy areas in and around Colombo suitable for construction. When piling operation is needed a suitable hard stratum with a significant bearing capacity should be identified. In many marshy and water logged areas this is a problem which can be minimized by applying a suitable EPS blocks either to retain the uniform bearing capacity or to control the differential settling of the said structures. Sometime impermeable barriers are to be placed and EPS can be used under such situations. In one study I plan to use EPS in the Petroleum tank field in Orugodawatta (Fig. 4). The land is waterlogged and located in a partially marshy area. The client needed to have a vehicle parking area and road network on the land where our consultants suggest of using EPS material. The material cost however is high due to specially selected material to be used, which could resist chemical reactions due to petroleum products in the vicinity. In general considering the extent of marshy and water logged areas close to Colombo the demand for successful application of LGM will be quite high.

Fig. 4. Grouting operation under petroleum storage tanks in the marshy lands at Orugodawatta, Colombo.

## THE COST FACTOR INVOLVED

As per the quotation we received both from local and international EPS manufacturers it is clear that the material cost at the moment is relatively high. The following tables (Table 3 and 4) produced some recent prices available for high quality and medium quality EPS blocks. As per the material cost is concerned it may not be attractive considering with the current market prices for other conventional construction methods. However, when one look at the local EPS material prices, the material either developed or manufactured locally could reduce the price effectively. As per the local labor is concerned, the employment of local manpower for the construction activities is time consuming and usually cumbersome to manage. By application of EPS or LGM, however, contractors and engineers could reduce the manpower and expect calculated protection for the structure. If the cost benefit is concerned I believe the trend with the introduction of LGM will minimize the cost factor in the future with increasing benefits.

## EDUCATIONAL AND MARKET ACTIVITIES

Since the general public and the clients in Sri Lanka are not aware of many possible applications of LGM, a vigorous educational and marketing strategy is needed. This can be done, in terms of having exhibitions, performing test cases and requesting participation of international companies who are using LGM for the construction. The method must be introduced to the prospective clients, contractors and engineers with a view to expose themselves for the vast possibilities related to applications of LGM. Construction of low cost high quality EPS or LGM under the present set of contacts is not a difficult task since the requirement for the material is increasing and several local companies are already in the business.

## SUMMARY

As per the local need as explained in the above sections one can logically argue that producing EPS or LGM locally is a very important stride one should take in order to overcome the present situation. With the funds available locally, the Soil Tech Ltd has already started building of low cost LGM blocks in Sri Lanka with locally available material such as lime, peat and coir products combined with reinforced concrete. I expect the outcome of this exercise could provide promising results and I need to start up vigorous marketing and research activity for the products to be introduced in to the local market. It is quite possible to engineer economic and safe structures using elementary design concepts and techniques, provided that some fundamental principles are applied supplemented with acute observations, brave application of engineering judgment and implementing the ideas with an open mind. I personally stressed employing vigorous marketing strategies, and organizing educational and social input to overcome the general skepticism among the people, including engineers and planners who are still favoring of conventional construction material

## REFERENCES


Bromhead, E.N., (1992). The Stability of Slopes. Balckie Academic & Professional. 411 pp.

Broms, B., (1971). Lateral earth pressure due to compaction of cohesionless soils. Proc 4th European Conf. on Soil Mechanics and Foundation engineering, Budapest, 373-384.

Cooray, P.G. (1984). The geology of Sri Lanka (Ceylon). National Museum of Sri Lanka Publication. 340pp.

Dahanayake, K. (1982). Laterites of Sri Lanka. A reconnaissance study. Mineral. Deposita, 17:245-246.

Dahanayake, K. (1990). Landslides triggered by high precipitation and neotectonic movements in the Highlands of Sri Lanka. Landslide News, 4:16-18.

Dissanayake, C.B. (1980). Mineralogy and chemical composition of some laterites of Sri Lanka . Geoderma, 23:147-155.

Eittreim, S.L. and Ewing, J., (1972). Mid-Plate Tectonics in the Indian Ocean. 77(32): 6413 –6421.

Graton, L.C., and Fraser, H.J., (1935), Systematic packing of spheres with particular relation to porosity and permeability, and experimental study of the porosity and permeability of clastic sediments; Jour. Geol., 43: 785.

Herath, J.W. (1973). Industrial clays of Ceylon – Geology, Mineralogy and appraisal for ceramic and other industries. Eco Bull., No 1., Geological Survey Department, Colombo. 1-113

Ingold, T.S. (1979), The effect of Compaction on retaining walls. Geotechnique 29(3): 265-283.

Jayasena, H.A.H., (1994). Reconnaissance Survey of Ratnapura - Godigamuwa Landslide. Report presented to the UNESCO- MAB Project, Natural Resources Energy and Science Authority of Sri Lanka (NARESA). 12 pp.

Jayasena, H.A.H., (1994). Mechanism of Earthquakes. GSSL Special Seminar Report. 14 pp.

Kulathilake, S.A.S., (1998) Application of Finite Element method to analyze Retaining wall behavior., Geotechnical Jour. SLGS 2(1): 14-27.

Malalgoda, D and Jayasena, H.A.H., (2000). Hydrological and geological appraisal of Nahaketiya-Koslanda Landslide in Sri Lanka. Abs. Annual Sessions Faculty of Science, Session III P: 20 p

McCrea, A.F, Anand, R.R. and Gilkes, R.J., (1989). Mineralogical and physical properties of lateritic pallid zone materials developed from granite and dolerite Geoderma, 47: 33-57.

Moorman, F.R. and Panabokke, C.R, (1961). Soils of Ceylon. Trop. Agric. 117:4-65.

Munasinghe, T. and Dissanayake, C.B., (1982). A plate tectonic model for the geologic evolution of Sri Lanka. J. Geol. Soc. India. 23: 369-380.

Premasiri, R., (1992). Personnel Communications

Seed, R.B. and Duncan, J.M. (1983), Soil Structure Interaction effects of Compaction Induced Stresses and Deflection, Geotechnical Engineering Research report No. UCB/GT/83-06, University of California, Berkley, U.S.A.

Senaratne, A. and Dissanayake, C.B., (1989). Environmental evolution of the Muthurajawela swamp and interpretation of its chemical profiles. Abstr., Symposium Geoscience and Environment. Geol Soc. 15.

Stimpson, B. (1979). Simple equation for determining the factor of safety of a planar wedge under various groundwater conditions Q.J. Eng. Geol. 12: 3-7

Sykes, L.R., (1970). Seismicity of the Indian Ocean And a Possible Nascent Island Arc Journal of Geophysical Research Between Ceylon and Australia. 75 (26): 5041-5055.

Tennekoon, B.L. (1998). Evaluation of the consolidation characteristics of residual soils. Geotechnical Journal, SLGS, 2(1): 28-32.

Vitanage, P.W. (1972). Post-Precambrian uplifts and regional neotectonic movements in Ceylon. Proc. 24th International Geol. Cong., Sec 3:642-654.

## Acknowledgements:

I am indebted to Messers Toru Hagiwara and Yoshiharo Sato of EDO Japan for supplying me with EPS material and quotations of Japanese products. Their continuous support extended towards me has paved the way for this publication. Most probably I could not finish this article without their continuous backing. Mr. Prasad Anthony of the Hubert Anthony Co Ltd in Colombo Sri Lanka is mentioned with gratitude for his supplying of EPS products for the initial tests. Dr. P.B.R. Dissanayake of the Structures Laboratory of the University of Peradeniya is mentioned for his support in carrying out static load tests for EPS blocks. Thanks goes to Ms. Sunethra Kanumale who assisted me in the preparation of diagrams. Those who supported me in many ways to organize and obtain data relevant for this article for which I could not personally thanked are mentioned with gratitude.

**Short Biography**

Chandra Jayasena is a Senior Lecturer and a founding Director of the Soil Tech Ltd. of Sri Lanka. He has been serving in the University of Peradeniya at the Department of Geology since 1980. However, in 1982 he took up a position as the Resident Hydro-geologist of the Water Resources Board and participated in a World Bank supported groundwater project in the Kurunegala District. In 1986 he proceeded to USA under Fulbright Scholarship program to complete an M.S in Earth Resources at the Colorado State University. He has started his PhD in Hydrology at the University of Arizona in 1990. He has been contributing to the hydrogeological and engineering geological activities both locally and internationally and published articles in applied geological, hydrogeological and engineering geological journals.

Table 1: Physical properties of Styrofoam available in Sri Lanka

| **Property** | **Unit** | **Results** | | |
|---|---|---|---|---|
| Density | kg/m$^3$ | 15 | 20 | 30 |
| Thermal Conductivity at 10°C | W/(m.K) | 0.036-0.038 | 0.033-0.036 | 0.031-0.035 |
| Stress at 10% Compression | N/mm$^2$ | 0.08-0.13 | 0.12-0.17 | 0.21-0.26 |
| **Water Absorption when kept under water (percent by volume)** | | | | |
| After 7 Days | % | 0.5-1.5 | 0.5-1.5 | 0.5-1.5 |
| After 28 Days | % | 1.0-3.0 | 1.0-3.0 | 1.0-3.0 |

Table 2: Static Load Test Results of the EPS blocks

| **Property** | **Unit** | **Results** | | |
|---|---|---|---|---|
| Density | kg/m$^3$ | 15 | 20 | 30 |
| Stress at 10% Compression | N/mm$^2$ | 0.13 | 0.12 | 0.12 (?) |

Table 3. Cost of several international EPS products

| **Material** | **Unit Price /m$^3$** | **Transport including loading at the port /m$^3$** | **Cost without Local Handling fee And unloading at the port /m$^3$** | **Anticipated final cost after adding 10% as handling fee in Sri Lanka.** |
|---|---|---|---|---|
| EPS Block (D-20 Fire retardation treatment (Oxygen index: more than 26) | Yen 17,000 | Ocean Freight rate per EPS = Yen 8,750 | Yen 25,750 | Rs. 19827.50 |
| Styrofoam Block (630 mm x 1220 mm x 2440 mm combustibility): | Yen 6,000 | Yen 169,000/container 55m$^3$/container | Yen 9,100 | Rs. 7007.00 |
| EPS Block (D-20 Fire retardation treatment (Oxygen index: more than 26) | Yen 18,800 | Yen 10,000 | Yen 28,800 | Rs. 22176.00 |

Table 3. Cost of local EPS products

| **DESCRIPTION** | **UNIT PRICE** | | | |
|---|---|---|---|---|
| EPS block dimensions | Low density | Standard density | High density | High density /m$^3$ |
| 8'x 4'x 6" (2.43x1.21x0.152) | Rs. 2,035/= | Rs. 2,394/= | Rs. 2,993/= | Rs. 6710.00 |
| 8'x 4'x 4" (2.43x1.21x0.100) | Rs. 1,366/= | Rs. 1,607/= | Rs. 2,009/= | Rs 6832.00 |

| **DESCRIPTION** | **QTY** | Retail price | Wholesale price |
|---|---|---|---|
| "Styrofoam" buds 20mm | 01 PKT (100 Buds per PKT) | Rs. 25/= | Rs. 20/= |
| "Styrofoam" balls 40mm | 01 No | Rs. 5/= | Rs. 3/= |