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A Study on Low Cost Alternative False Ceiling

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Abstract:
The present investigation was focused on studying the design and development of false ceiling board using high quality T- Grid suspension system method, which is extensively used to suspend lay-in ceiling tiles and mineral fiber ceiling tiles to the ceiling. The aim was to develop a light weight and good strength performance false ceiling board with best grade Expanded Poly Styrene and pre-painted polyester coated galvanized steel for sturdy construction and excellent finishing. In this project, pre-painted hot dip galvanized steel with anti-rusting properties were used as a snap fitting system over the conventional system to elucidate its economical feasibility, fast and easy installation qualities and flexible design that can be dismantled and reused easily. Finally, the EPS boards were fixed in between the grid formations after finishing the T-section joints and joining the wires with these grid formations. This high quality durable system was identified as the best system and well suited for cost convenience, easier installation and greater field flexibility. Further, it provided a smooth homogeneous surface to the roofing as it creates compartmentation and also added to acoustical treatment and efficient air conditioning within the environment. Additionally, they are visually presentable, easy to maintain and have a long life span.
Keywords: *False Ceiling, Expanded Poly Styrene (EPS), T-Grid suspension system, pre-painted hot dip galvanized steel, low-cost.*

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I. INTRODUCTION

Nowadays, False Ceiling also referred as drop ceiling or suspended ceiling or T-bar ceiling, has predominantly become a staple form of modern construction and architecture in both residential and commercial applications. A few decades before, much importance were provided to flooring and walls with the finest marbles and plastering beautiful shades respectively. False ceilings considered to be the best inventions in the era of architecture provide excellent home decoration and spacious if designed well. Choosing the right material is an essential criterion for the false ceiling's durability and quality. Besides giving an elegant look to the buildings, false ceilings also help in keeping off the excess heat and noise from outer environments. The commonly used false ceiling boards are thermocol, gypsum, aerolite, PVC and wood.

EPS False Ceilings are an excellent alternative to the high cost and expensive interior and ceiling designs and are very much in trend because of easy installation and can be moulded into numerable eye catching designs. Detailed patterns and fine work can be made into them left white or painted in any colour and can be installed easily. EPS as described, is a really versatile material and being economical EPS false ceilings are very much in demand. Expanded Poly Styrene (EPS) commonly called as Thermocol has wide range of applications in construction and packaging industries. The EPS market is expected to grow from USD 15.5 billion in 2018 to USD 20.1 billion by 2023, at a CAGR of 5.3% during the forecast period [24]. There is an increase in EPS usage as roof insulation material in energy efficient buildings with ever increasing awareness among the field experts and building owners to save energy at a low cost and due to the versatility in thermal insulation applications [28]. Thermocol boards are made up of polystyrene. Styrene is an unsaturated liquid hydrocarbon obtained as a petroleum by-product and polymerized to form a compound called polystyrene which is blended with CO_2 to form a foam (Styrofoam) that eventually solidifies to form thermocol. Figure 1 shows the different forms of EPS - EPS Resin, Expanded beads and Molded foam.

Most ceiling tiles are made from mineral fiber, but other materials such as fiberglass are also available. Mineral fiber tiles typically have a high Noise Reduction Coefficient (NRC), which means they are good at absorbing sound within a space to prevent echo or loud environments. U. S. Patent No. 1,470,728 for modern dropped ceilings was applied for by E. E. Hall on May 28, 1919, and granted on October 16, 1923 [30]. Modern dropped ceilings that were built using interlocking panels had the only access for repair or inspection of area above the panels by starting at edges of the ceiling, or at a specific design by removing the panels completed, to be reinstalled which was very time-consuming and expensive. But, later on Patent Number US 2,984,946 A granted to Donald A. Brown of Ohio for Accessible Suspended Ceiling Construction became an remarkable invention that helped suspended ceiling construction in which access is readily obtained at any desired location [22] and he was credited as the inventor of the Dropped Ceiling [6]. Subsequently, an effective building design requires balancing multiple objectives like aesthetics, acoustics, environmental factors, and integration with the building's infrastructure [19].

In 1839, Eduard Simon created a new product made of large number of styrene linked together through polymerization called as the expanded polystyrene sheet (EPS) with main advantage of not including any halogens during the production processes and non-destructive to Ozone layer and thus, its consumption in the construction industries have gradually increased in recent years [23]. EPS is a well-established insulation material used for various applications as it has light yet rigid foam with good thermal insulation and high impact resistance. Further, it possesses high load-bearing capacity at low weight, absolute water and vapor barrier, air tightness for controlled environments, long life, low maintenance, fast, and economic construction. The foam in EPS is a lightweight cellular plastic consisting of small spherical-shaped particles containing about 98% air. This microcellular closed cell construction provides EPS with its excellent insulating and shock absorbing characteristics [29]. Previous studies have clearly shown that starch and cellulose-derived composite EPS are more likely to substitute EPS based on its environment-friendly characteristic [7,8,17]. The purpose of the present investigation was to develop a false ceiling board using Expanded Polystyrene Sheet (EPS) based on an advanced range of high quality T- Grid suspension system method. The main aim of this study was to prove that the Thermocol false ceiling as a modular T-Grid pre-painted hot dip galvanized steel system developed as snap fitting system are highly advantageous over the conventional system as they are economical, fast and easy to install, flexible in design that can be dismantled and reused easily. The cost estimation for each element required for the project— materials, total cost of providing L-section, total cost of providing T-section, total cost of GI wire were evaluated and reported and a total amount that determines a project's budget was calculated.

II. LITERATURE REVIEW

The design of engineering structures must ensure that the structure is safe under the worst loading and also during normal working conditions, the deformation of members does not distract from its appearance, durability or performance of structure [18]. EPS is one of the alternative building technologies aimed at providing affordable and sustainable building material for housing. Sustainability of buildings are a predominant factor for the construction industry and therefore, sustainable buildings are characterized by lower construction costs for energy consumption and operations, environmentally friendly, save natural resources and thus, comfortable and healthy for their users [16, 20]. A building material that meets the safety standards (including seismic resistance) and the dweller’s comfort requirements must also be thermally insulating, light weight and inexpensive [15,20]. Such necessities are today made possible using the EPS initiative which represents one of such new materials that have paved way into the previously conservative construction industries [9]. Initially, EPS being a multipurpose plastic material having plethora of applications was used as insulation foam for closed cavity walls, roofs and floor insulation [10]. While, Ngugi *et al.,* (2017) suggested that following continued research and innovation, EPS usage has extended in the building and construction industry in road construction, bridges, floatation, railway lines, public buildings, drainage facilities and family residences. EPS are more commonly used for wall panels and slabs erected with steel meshes serving as reinforcement and are available in various types and sizes for building construction. The EPS 3D reinforced wall system usually transfers shear and compression forces along the wall plane which is completed by applying concrete layers of acceptable thickness on both sides to perform the dual functions of protecting the reinforcements against corrosion and transference of compressive forces [9].

Studies carried out by Ede *et al.,* (2014) on applications of innovative plastic material in building industry with special regards to performance perception revealed great satisfaction among their clients and residents and further ranked in high performance of EPS materials, characterized by recyclability, reliability, versatility and moisture resistance characteristic of EPS building products. The paper reports that the adoption of plastic in civil constructions have dramatically increased due to improved material performance, efficient use of technologies in new applications, and the need for lightweight, durable materials and insulation purposes with the proven strength of plastic materials used in commercial and residential construction over the past 30 years [10, 20]. EPS technology is widely used in USA, India, Japan, Germany, Canada, Mexico, Britain, Qatar, Nigeria, Mozambique and Kenya since it provides environmental, technical, commercial and social benefits as a construction material [24].

EPS material prohibits a thermal conductivity in the range of 0.032 - 0.038W/(m・K) when compared to concrete which falls in the range of 0.4-0.7 W/(m・K). This is mainly considered as important because its range is much lower helping to reduce the energy consumption and thus, minimizes energy required for heating or cooling up to 60-80% depending upon the thickness as well as density of EPS used. The walls with EPS embedded in concrete and steel reinforcement (EPSCSR) prove to be very comfortable for the inhabitant in terms of heating and cooling as well as sound insulation for peaceful indoor environment [23]. The material is therefore suitable to regulate extreme temperatures in a building. The unit weight of EPS embedded structure is upto 35% less than the conventional concrete structure. As a result of the reduced weight, the pre-assembled units reduce the overall cost of structure significantly and therefore, EPS embedded structure results in a sustainable and economical construction. [20].

Sayadi *et al.,* (2016) studied the effects of EPS particles on fire resistance, thermal conductivity and compressive strength of foamed concrete. This article concludes that based on the experiment involving foamed concrete and EPS Light Weight Concrete of different densities and volumes, the volume expansion of EPS leads to remarkable reduction in thermal conductivity, fire endurance, and compressive strength of the concrete [26, 29]. Similarly, Shi *et al.*, (2016) analyzed the dynamic cyclic loading and reported that EPS concrete can be implemented in application that requires long-term cyclic loading such as protection of buried military structure due to its durability and energy absorbing properties. Many studies have been conducted on waste EPS-derived concrete and they are recycled as aggregate for LWC and its properties are examined and compared with other conventional materials in order to promote sustainability development [29]. For example, Dissanayake *et al.*, (2017) made a comparative study constructing three single storey houses using three different materials: burnt clay brick, cement sand block, and recycled EPS where house's wall was made with EPS panels. Despite their similar performances in embodied energy, carbon emission and cost, the paper suggests that recycled EPS is greener alternative for conventional walling material especially in location that has short supply of sand [4, 29]. Similar findings were obtained by Bhutta *et al.*, (2011) where EPS waste was recycled into resin for production of polymer mortar panels (PMPs) by mixing the waste in methyl methacrylate (MMA) solution and observed that on the basis of flexural behavior test, the EPS–MMA based PMP had better flexibility and high load-bearing capacities than polymer-impregnated mortar panel [3, 29]. The paper [11, 29] highlights that EPS waste can also be dissolved into resin using solvents like toluene and acetone to produce polymer–cement composite that has potential as a commercial construction material and radioactive waste deactivator**.** On the other hand, Kharun and Svintsov (2017) in their experiment added various reinforcing materials, plasticizing and air-entraining additives to develop a reinforced polystyrene concrete mixture composition including expanded polystyrene, crushed polystyrene, portland cement type I, gypsum, gaize, chrysotile asbestos fiber, plasticizer aqueous solution of polyacrylamide, carboxymethyl cellulose, tartaric acid, saponified wood resin and water to be used for the production of thermal insulating and structural thermal insulating material of buildings of various purposes.

Structural evaluations of structural insulated panel (SIP) using computer software have been practiced by several researchers. For instance, Bajracharya *et al.*, (2013) conducted a structural analysis of EPS sandwich panels for slab application using structural software Strand7 based on finite element method and the results obtained were in good agreement with the experimental results, thus expanding SIP usage in production of lighter structural slab with better heat and sound insulation [1, 29]. Alternatively, when Park *et al.*, (2016) performed study in vibroacoustic application of graphite-embedded EPS foam sandwiched between floors found that addition of graphite flakes into polystyrene matrix increased thermal insulation as a result of graphite particles reflecting radiant energy. The foam became stiffer as a result of change in morphology and such improvements led to production of thinner and stronger insulation panel declining the low frequency (below 100 Hz) floor impact noises [21,29]. Subsequently, depending on the area of application of roofing, a wide range of techniques on EPS insulation have been recommended by experts and organizations till date [2]. Since previous methods were found expensive and laborious for roof insulation, however, the studies by Sowriraajan and Dixit (2011) revealed that surface treatment of EPS board with a mixture of gypsum plaster reinforced with bleached natural fibre/paper would be a promising combination towards mitigating fire hazard in existing rooms with EPS false ceiling enormously without compromising on room aesthetics. Zeleke and Rotich (2021) developed a light weight and good strength performance false ceiling board from polyvinyl-acetate (PVAc) composite reinforced with false banana fibres and filled with sawdust that are fully biodegradable. They evaluated mechanical properties of developed composite board in terms of its tensile strength, flexural strength, and compressive strength and physical properties including its density and moisture absorption and reported that the developed false ceiling board composite showed good performance in terms of the evaluated properties.

III. MATERIALS AND METHODS

The present project work was carried out during 2016-2017 in the Department of Civil Engineering, Vidya Vikas Polytechnic, Department of Technical Education (DTE), Bangalore, India. Expanded Polystyrene (EPS) boards available at Mysore local market being used for the purpose of the false roofing systems in industrial shop floors, shopping malls, class rooms and office rooms were procured and analyzed in this investigatory project.

Tee Grid System – Installation of False Ceiling:

The false ceiling was well constructed for the civil engineering department staff room in the college having dimensions of 32 x 22 with total area of 702 sqft. This was performed in providing an advanced range of high quality Tee Grid System in 24mm/15mm, which is extensively used to suspend lay-in ceiling tiles and mineral fiber ceiling tiles to the ceiling. This is a high quality durable system since its fabricated using premium quality raw material for its long life [13]. Figure 2 presents the image of Stainless Steel Galvanised T Grid system. Firstly, after obtaining the exact measurements of the room where the suspended ceiling had to be installed, the exact dimensions were drawn to scale on a graph paper and also the layout for the planned ceiling was sketched on this paper. In this project, an exposed lay-in system to fit 600 mm x 600 mm ceiling modules were utilized for a 2' x 2' pattern. While drawing, the main tees were positioned so that the border patterns at the room edges are equal on both sides and as large as possible. The cross tees were spaced so the border panels at the ends of the room are equal and as large as possible. The false ceiling to be installed was suspended by a 4mm diameter adjustable with quick fit hanger rod system. A minimum of 3'' to 4'' clearance was allowed between the old ceiling and the new ceiling for installation of the ceiling panels.

After locating the exact position for the suspended ceiling, a level was used to draw a line completely around the room indicating where the wall angle will be applied. A level for accuracy of the original ceiling level was analyzed and the wall angle was set low enough to conceal pipe ducts and therefore after measuring and calculating the wall angle, a level was used to apply the wall angle at a proper height around the room. The wall angles were fastened securely to the wall at all points and nailed firmly to studs, or using screw anchors and other masonry fasteners on brick or masonry walls. The wall angle was positioned so that the bottom flange rests on the level line drawn on the wall followed by, overlapping the wall angle on inside corners and mitering the wall angle on outside corners. Later for locating and hanging suspension wires for main tees, sketch of the room was refereed for the location of all main tees. Since main tees should always run at right angles, the position of each main tee was located and a tight line was stretched from top edge of the wall angle on all sides of the room at each position where the tees had to be placed.

Now, the suspension wires were cut to the proper length which longer than the distance between the old ceiling and the new guideline string that has been stretched to indicate the position of each main tee. The first suspension wire for each main tee was located directly above the point where the first cross tee meets the main tee by checking the original sketch of the room to determine this location. Then, they were fastened securely and applied to the ceiling by drilling with screw eyes, screw hooks and nails. A suspension wire was attached every 2' along the level guideline and stretched to remove any kinks and a 90° bend was made where the suspension wire crosses the level line.

Main Tee shall be in 38mm/33mm and the height exposed portion (polyester coated) shall be 24mm. The distance from the wall to the first cross tee was determined referring to the layout sheet and this distance was measured along the top flange of the main tee to locate the slot just beyond this point. From this slot, the same distance was measured back, subtracted 1/8" to see the main tee at that point. The 1/8" subtraction was for the thickness of the wall angle. Wherever the wall angles were not square the cross tee slots were positioned accordingly. Since the room was wider than 12' the main tee was spliced allowing 1/8" for the thickness of the wall angle. The splice was aligned so that the suspension wires were correctly positioned. Using a long level, the main tees were installed such that they are all in level with the wall angle already mounted.

Cross tee was 26mm height having exposed portion to be 24mm. All system components were made of roll formed from hot dipped galvanized steel of 0.30mm thickness with zinc coating of not less than $120g/m^2$ and a minimum tensile strength of 240 MPa. Whereas, the measurements of wall angle was 24mm height x 24mm width having expose portion made of 0.40mm thickness pre-coated coil. Both ends of the Main Tee have integral splices, which were enjoined firmly by inserting a tab on the one end of one section into the slot in the adjoining section. The cross tees were installed by inserting their ends into the slots in the main tees. The location of the cross tees was determined based on 2' x 2' pattern selected. The lock tab on the cross tee to be on the outside of the slot was ensured and the border cross tees were installed between the wall angle and the last main tee. From the last tee to the wall angle was measured allowing 1/8" for the thickness of the wall angle. The cross tees were cut and installed by inserting the connector in the main tee and resting the cut edge on the wall angle.

The exposed flange finish was pre-painted polyester coated galvanized steel not less than 0.30mm in off-white color with a coating thickness of 20 microns top coat and 8 microns primer alkyd backer on backside. The main runner has fire notches to sustain the grid system during fire. The final main and cross tee arrangement will look similar showing main and cross tees arranged for a 2' x 2' layout. The ceiling panels were dropped into position by tilting them slightly, lifting them above the framework and letting them fall into position [5].

Therefore, the procedure adopted in this project is briefly summarized below.

1. The dimension of room to construct false ceiling was measured
2. The quantity of material required for work was estimated
3. With the help of tube level the levels were marked
4. On the marked levels, the points for L-section and T-section joints were marked
5. The L-section joint around all the sides of wall at the required height was installed
6. The points were marked to form a grid by using T-section joint
7. For support of ceiling, the copper wire was provided from top roof
8. After finishing T-section joints, wires were joined with the grid formation
9. Finally, the Expanded PolyStyrene (thermocol boards) were fixed in between the grid formation.

IV. RESULTS AND DISCUSSION

The investigation showed modular T-Grid pre-painted hot dip galvanized steel system developed as snap fitting system having more advantages compared to the conventional system. The project observed false ceiling construction at a low cost with fast and easy installation due to snap fitting qualities. The design was found to be highly flexible, capable to be dismantled and reused easily which was significantly in accordance to the layout for the planned ceiling that was sketched on the graph paper. Similar findings have been reported by Zeleke and Rotich (2021) and Raj *et al.,* (2014). Good ideal acoustics for the space was achieved with efficient air conditioning maintained inside the building environment. The final cost of project for civil department staff room inclusive of all elements such as, material requirements, L-section, T-section and GI wires was estimated and calculated for dimension of room 32 x 22 with total area 702 sqft. The total cost of providing L-section with total perimeter 180 Rft and T-section with total area 580 sqft was calculated as Rs.3600 and Rs.23200 respectively. A total of 172 Expanded PolyStyrene (EPS) or thermocol boards of 2 x 2 sqft size were used costing Rs. 3440. A total of 8 kg GI wire costing 80Rs. per kg was used in this project amounting to Rs.640 totally. Overall, the final total cost of this investigatory project was calculated and determined as Rs. 30880. The EPS false ceiling was constructed accordingly and the whole staff room was assembled as presented in Figure 3.

Finally, EPS have low weight, excellent mechanical resistance properties, a better alternative for load-bearing roof insulation and road construction. Ngugi *et al.,* (2017) suggested that EPS's chemical resistance make it completely compatible with other materials used in construction including cements, plasters, salt, fresh water and admixtures and its versatility would result in an easy cut into the shape or size required by the construction project. Also, EPS is unaltered by external agents like fungi or parasites as they find no nutritional value in the material. EPS is 100% recyclable and thousands of tonnes are recycled every year in developed countries like the United Kingdom (UK). Sulong *et al.,* (2019) reviewed that in Norway, usage of EPS geofoam as backfilling has prevented the gradual sinking of bridge deck by reducing the load applied to the weak foundation.

V. CONCLUSION

EPS is observed as light-weight rigid foam possessing good thermal insulation, capable of load-bearing at low weight, impact resistance, absolute water and vapor barrier, air tightness for controlled environments, longer life, low maintenance, fast and economic construction. In an outline, the present investigation paves way for exposing the new technique establishing the feasibility and benefit of EPS as a low cost alternative false ceiling technology that could be adopted to develop sustainable buildings and the study was fruitful to prove the significant potential of EPS false ceiling, evidently showing the cost of construction to be highly economical. Further, this study also indicates that EPS could be used for acoustical treatment and good air conditioning. EPS is economical, easy to install and uses less labor to complete the installation in a minimum time frame as compared with conventional extruded aluminum tee system. Interchangeability of main and cross tees between systems promotes lower inventory requirements and greater field flexibility. The straight entry locking feature of the section allows the system to be installed easily within close proximity of the overheads. The system promotes complete design flexibility and is capable of sustaining loads normally designed into the suspended tee system [Referred to load table - IS800-1984 and IS875 (Part-1, 2 & 3)]. Overlap type of cross tee provides complete flush joint, eliminating gaps between main runner and cross tees and ensures rigidity at fixtures. In-line cross tees provide true double-lock action.

VI. FUTURE PROSPECTS

An increase in energy prices is forcing consumers to increase their thermal efficiency to reduce their energy consumption, thus, driving the market for EPS-based roofing systems. In India, the construction industry in value terms is expected to record a CAGR of 15.7% to reach USD 738.5 billion by 2022 [25]. Since, Expanded PolyStyrene is presently trending in popularity and acceptance highly advantageous with numerous construction applications, they can be mixed with eco-friendly raw materials to develop sustainable green buildings. Such newer technologies will evolve substantially having good recognition and standard in India widely-used in residential and commercial construction.

Abbreviations

EPS- Expanded PolyStyrene, PVC- Polyvinyl chloride, CAGR – Compound Annual Growth Rate, NRC - Noise Reduction Coefficient, GI wire - Galvanized Iron Wire, EPSCSR - EPS embedded in concrete and steel reinforcement, EPSLWC – Expanded PolyStyrene Light Weight Concrete, PMPs - Polymer Mortar Panels, MMA - Methyl Methacrylate, SIP - Structural Insulated Panel, CBRI - Central Building Research Institute, PVAc - polyvinyl-acetate composite, MPA - Megapascal, Rft – Running Feet, sqft – Square Feet

REFERENCES

[1]. Bajracharya, R., Lokuge, W., Karunasena, W., Lau, K. and Mosallam, A. (2013). "Structural evaluation of concrete expanded polystyrene sandwich panels for slab applications". 22nd Australasian Conference on the Mechanics of Structures and Materials, Sydney, Australia. CRC Press: London.

[2]. Bakhtiyari, S., Taghi-Akbari, L. and Barikani, M. (2010). "The Effective Parameters for Reaction-to-fire Properties of Expanded Polystyrene Foams in Bench Scale". Iranian Polymer Journal, 19 (1): 27-37.

[3]. Bhutta, M.A.R., Ohama, Y. and Tsuruta, K. (2011). "Strength properties of polymer mortar panels using methyl methacrylate solution of waste expanded polystyrene as binder". Construction and Building Materials, 25(2): 779-784.

[4]. Dissanayake, D., Jayasinghe, C. and Jayasinghe, M. (2017). "A comparative embodied energy analysis of a house with recycled expanded polystyrene (EPS) based foam concrete wall panels". Energy and Buildings, 135: 85-94.

[5]. Dissertation Report False Ceiling. (2019). https://dokumen.tips/documents/dissertation- report- false-ceiling.html

[6]. Don Brown remembered as a man with lots of ideas. *"The Morning Journal."* January 19, 2010. Retrieved January 14, 2014. https://en.wikipedia.org/wiki/Dropped_ceiling

[7]. Doroudiani, S. and Kortschot, M. T. (2004). "Expanded Wood Fiber Polystyrene Composites: Processing–Structure–Mechanical Properties Relationships". Journal of Thermoplastic Composite Materials, 17(1), 13.

[8]. Doroudiani, S., Chaffey, C. E. and Kortschot, M. T. (2002). "Sorption and diffusion of carbon dioxide in wood-fiber/polystyrene composites". Journal of Polymer Science, Part B: Polymer Physics, 40(8), 723 – 735.

[9]. Ede, A. N. and Ogundiran, A. (2014). "Thermal Behaviour and Admissible Compressive Strength of Expanded Polystyrene Wall Panels of Varying Thickness". Current Trends in Technology and Science, 3(2): 110 -117.

[10]. Ede, A. N., Alegiuno, V. and Oluwa, P. (2014). "Use of Advanced Plastic Materials in Nigeria: Performance Assessment of Expanded Polystyrene Building Technology System". American Journal of Engineering Research (AJER), 3(4): 301-308.

[11]. Eskander, S.B. and Tawfik, M.E. (2011). "Polymer–cement composite based on recycled expanded polystyrene foam waste". Polymer Composites, 32(9): 1430 - 1438.

[12]. Hangzhou Fuyang Longwell Industry, EPS Foam Making Machine Factory. http://m.lweps.com/eps-machine/eps-preexpander/eps-foam-making-machine-factory.html

[13]. IndiaMART-Roofing and False Ceiling-Ceiling Accessories-T Grid Ceiling. M/S R K Engineers & Traders. https://www.indiamart.com/proddetail/t-grid-ceiling-22564061397.html

[14]. Kharun, M. and Svintsov, A.P. (2017). "Polystyrene concrete as the structural thermal insulating material". International Journal of Advanced and Applied Sciences, 4(10): 40-45.

[15]. Lee, J. A., Kelly, H., Rosenfeld, A., Stubee, E., Colaco, J., Gadgil, A., Akbari, H., Norford, L. and Burik, H. V. (2006). "Affordable, safe housing based on expanded polystyrene (EPS) foam and a cementitious coating". Springer Science, J Mater. Sci41: 6908–6916.

[16]. Mesaros, P., Spisakova , M., Kyjakova, L. and Mandicak, T. (2015). "Expanded polystyrene as the bearing building material of low energy construction". In IOP Conference Series: Materials Science and Engineering, TSU.

[17]. Mihai, M., Huneault, M. A. and Favis, B. D. (2007). "Foaming of Polystyrene/Thermoplastic Starch Blends". Journal of Cellular Plastics, 43(3), 215.

[18]. Mosley, W. H., Bungey, J. H. and Ray, H. (1999). Reinforced Concrete Design, 5th Edition ed.

[19]. New Trends in Ceiling Designs and Materials, retrieved January 15, 2014. https://en.wikipedia.org/wiki/Dropped_ceiling

[20]. Ngugi, H. N., Kaluli, J.W. and Abiero-Gariy, Z. (2017). "Use of Expanded Polystyrene Technology and Materials Recycling for Building Construction in Kenya: A review". American Journal of Engineering and Technology Management, 2(5): 64-71.

[21]. Park, H. S., Kim, Y., Oh, B. K. and Cho, T. (2016). "Compressive properties of graphite-embedded expanded polystyrene for vibroacoustic engineering applications". Composites Part B: Engineering, 93: 252 - 264.

[22]. Patent US 2,984,946 A - Accessible Suspended Ceiling Construction, retrieved January 12, 2014. https://en.wikipedia.org/wiki/Dropped_ceiling

[23]. Raj, R., Nayak, M.K., Akbari, M.A. and Saha, P. (2014). "Prospects of expanded polystyrene sheet as green building material". International Journal of Civil Engineering Research, 5(2): 145-150.

[24]. Reportlinker. 2018. Expanded Polystyrene Market by Product Type, End-use Industry and Region - Global Forecast to 2023. Full report: https://www.reportlinker.com/p04883665

[25]. Report on Extruded polystyrene market - growth, trends, covid-19 impact, and forecasts (2021 - 2026). https://www.mordorintelligence.com/industry-reports/extruded-polystyrene-market

[26]. Sayadi, A. A., Tapia, J. V., Neitzert, T. R. and Clifton, G. C. (2016). "Effects of expanded polystyrene (EPS) particles on fire resistance, thermal conductivity and compressive strength of foamed concrete". Construction and Building Materials, 112: 716-724.

[27]. Shi, W., Miao, L., Luo, J., Wang, J. and Chen, Y. (2016). "Durability of Modified Expanded Polystyrene Concrete after Dynamic Cyclic Loading". Shock and Vibration, vol. 2016, Article ID 2391476.

[28]. Sowriraajan, A. Ve. and Bhaskar Dixit, C. S. "Improvement of fire safety in rooms with existing expanded polystyrene roof insulation". Proceedings of Fire Science and Technology - Research & its Implementations. November 3-4, 2011.

[29]. Sulong, N.H.R., Mustapa, S.A.S. and Rashid, M.K.A. (2019). "Application of expanded polystyrene (EPS) in buildings and constructions: A review". Journal of Applied polymer science, 136: 47529.

[30]. Suspended Ceiling Patent, retrieved January 14, 2014 - https://en.wikipedia.org/wiki/Dropped_ceiling

[31]. Zeleke, Y. and Rotich, G.K. (2021). "Design and Development of False Ceiling Board Using Polyvinyl Acetate (PVAc) Composite Reinforced with False Banana Fibres and Filled with Sawdust". Hindawi International Journal of Polymer Science, Volume 2021, Article ID 5542329.

[32]. Referred to load table - IS800-1984 and IS875 (Part-1, 2 & 3)]. Indian Standard Code of Practice for general construction in steel https://worldofcivil.files.wordpress.com/2013/04/is800-1984.pdf

Figures:

Figure 1: Different forms of EPS showing beads formation through expansion of resin that are molded into desirable shape. [12,29]

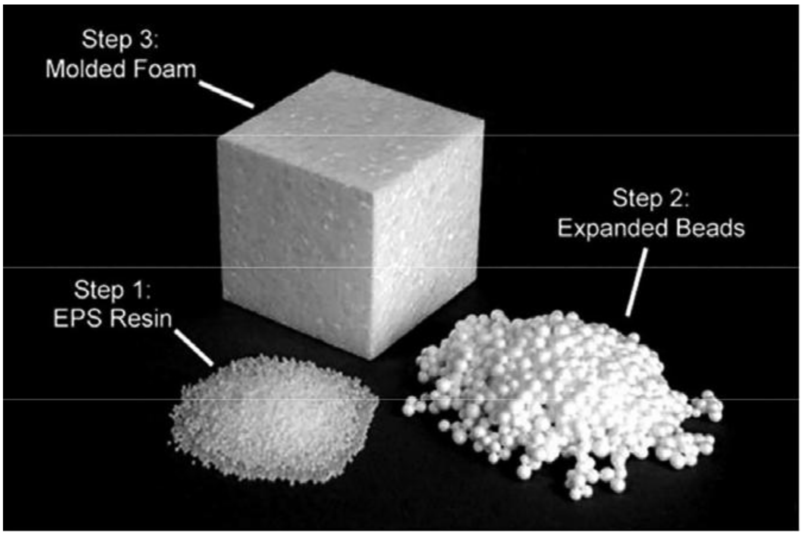

Figure 2: Stainless Steel Galvanised T Grid Ceiling.[13]

Figure 3: Construction Process **-** Installation of EPS False Ceiling