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Schematic Design Report on Shed Gallery for Avalanche Hit Mountainous Roads of India

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ABSTRACT: An avalanche is a mass of snow sliding, tumbling or flowing down an inclined surface. Mountain avalanches are much larger and conditions which cause the event of avalanche are more complex and sometime catastrophic. However, such large avalanches are often naturally released, when the snowpack becomes unstable and layers of snow begin to fail rolling down the hill slopes, sometime creating havoc in the downhill area mainly in there is presence of any infra-project, road network or places of Human inhabitants. In recent year, India is facing series of issues in the Border Roads of the Himalayan neighbouring countries mainly in the states of Arunachal Pradesh, Jammu & Kashmir, Uttarakhand, Sikkim & Ladakh.

KEY WORDS: Avalanche Mitigation, avalanche shed gallery, avalanche track, runout zone, dry snow

I. INTRODUCTION:

The inhabitants of mountainous areas have always been affected by the risk of avalanches. The need to live alongside this threat has led to attempts to mitigate the risk by constructing intricate systems of artificial structures. The deforestation, sometimes indiscriminate, of some areas and the development of tourist infrastructures has resulted, on the one hand, in the reduction of natural barriers to the triggering of snow instability phenomena and, on the other, to an increase in the need to guarantee the safety due to a different use of the territory - not to mention the need to protect residential areas and roads and railway lines.

An avalanche occurs when a mass of snow suddenly starts to move downhill due to a breakdown of the snow's equilibrium conditions. The movement of the snow may be the result of natural causes e.g. the wind or accidental reasons e.g. skiers on the slope, etc. As it moves downhill the avalanche may drag other snow with it, becoming increasingly large, and it can travel at speeds of more than 300 km/h. almost all mountain valleys may be considered to be subject to this hazard.

Avalanche hazard means the possibility of a dangerous event occurring, maybe in a remote area high up in the mountains, where there are no persons or objects: there is a clear hazard but no risk. However, avalanche risk means that there is a real hazard and there are persons or objects at risk.

Forces which act inside a layer of snow and possible detachment points can be categorised in several way. Elements characterising the detachment zone are as below:

- Slope angle
- Orientation with respect to wind direction
- Exposure to sun's rays
- Altitude
- Morphology
- Presence of trees
- Surface area of slope

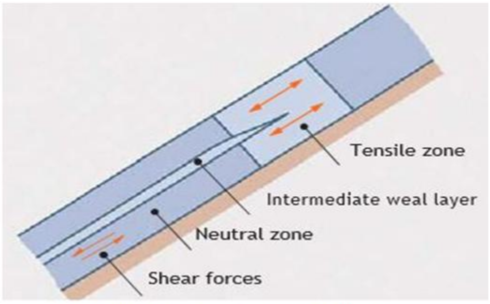

Fig 1: Forces acting on Snow Rack

An avalanche has three main parts. The **starting zone** is the most volatile area of a slope, where unstable snow can fracture from the surrounding snow cover and begin to slide. Typical starting zones are higher up on slopes. However, given the right conditions, snow can fracture at any point on the slope.

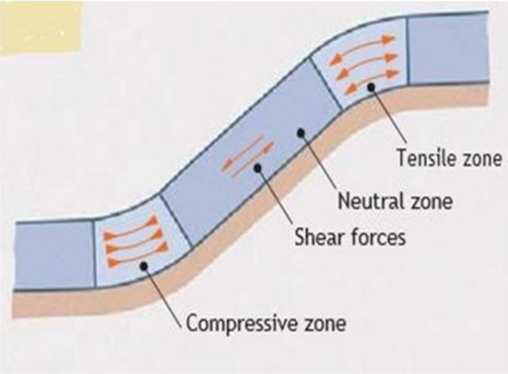

Fig 2 Stress induced in Snow Rack

The **avalanche track** is the path or channel that an avalanche follows as it goes downhill. Large vertical swaths of trees missing from a slope or chute-like clearings are often signs that large avalanches run frequently there, creating their own tracks. There may also be a large pile-up of snow and debris at the bottom of the slope, indicating that avalanches have run.

The **runout zone** is where the snow and debris finally come to a stop. Similarly, this is also the location of the deposition zone, where the snow and debris pile the highest.

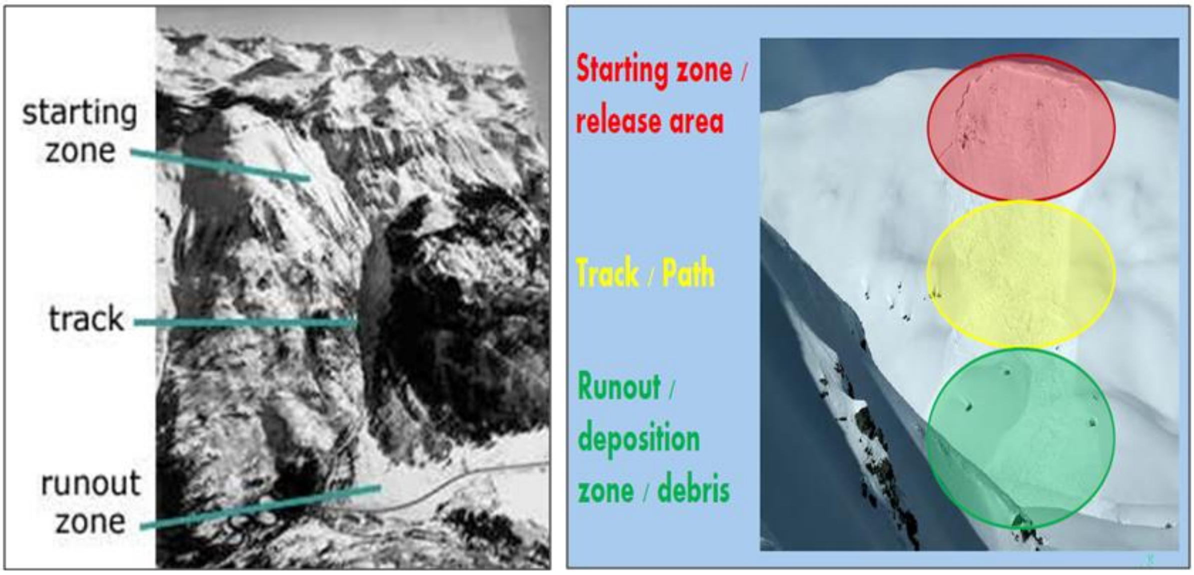

Fig 3. Formation of Avalanche

Several factors may affect the likelihood of an avalanche, including weather, temperature, slope steepness, slope orientation (whether the slope is facing north or south), wind direction, terrain, vegetation, and general snowpack conditions. Different combinations of these factors can create low, moderate, or extreme avalanche conditions. Some of these conditions, such as temperature and snowpack, can change on a daily or hourly basis.

Mitigation of hazards occurring due to Avalanche can be dealt with various environment friendly methods by erecting and positioning snow barrier structures. The snow barrier structures act on the slipping and sliding mechanisms of the layer of snow in a downhill direction, creating a stagnation zone on the upslope side characterised by compression forces which absorb a part of the dangerous shear forces in the weak layers and limit the propagation of the shear fractures. In this way there is a reduction in the shear forces and a consequent increase in the stability of the layer of snow.

The layer of snow exerts a pressure which must be absorbed by the nets and transmitted to the ground by means of a system of posts and anchors. The flexibility of the system results in a reduction of the pressure exerted by the snow on the structure in a parallel direction to the slope. The stress depends on the slope angle, the thickness of the layer of snow, the environmental conditions and the exposure of the slope itself.

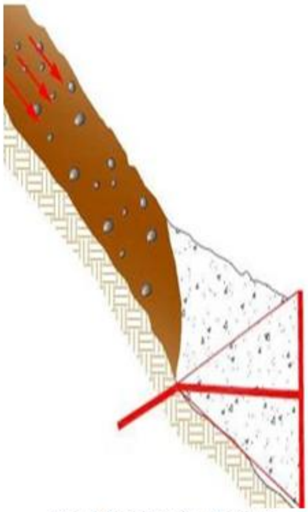

Fig 4 Avalanche Barrier

The snow barriers must be positioned in the area of the potential detachment of the snow. It is necessary to install various rows of structures, on the upslope and downslope sides of a potential failure point. This limits the propagation of the shear failure and the resulting movement of the mass of snow.

The snow barriers are designed in order to stabilise the layer of snow at the potential avalanche detachment zone, thereby preventing triggering of the avalanche.

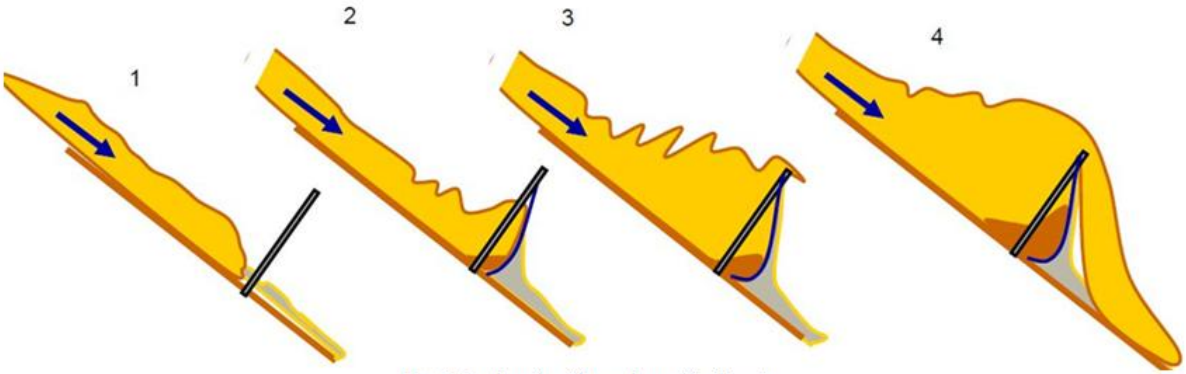

Fig 5 Avalanche Flow along the Barrier

Snow barriers should be easily adapted to ground surface irregularities resulting in to a perfect solution in situations where the ground alignment is irregular, where it would be difficult to adopt more rigid structures. An advantage of snow barriers is the reduced environmental impact due to their limited visibility, during both the winter and summer.

Snow barriers must be designed with few components which make them both simple and efficient: steel tubular struts, steel cable panels, steel mesh fitted to main cable panels, upslope and downslope anchors as well as end point anchors in order to guarantee the stability of the system.

Research Methodology: In this study, Proper knowledge of the forces from avalanches and wet avalanches, soil/rock masses and rock falls on various structures is considered to be major parameters for adequate structural design. Protective structures comprise of steel fences, flexible nets and wire systems, deviation structures and embankment dams, with anchor connections and energy absorption elements. Barrier and guard structures generally display highly nonlinear behaviour and there is a strong interaction between the impacting mass the structure and resilience of the structure. The structure must be designed with integrated ability to adapt to the changing conditions and maintain or recover functionality after the disruption or the ability to recover quickly from a setback or other adversity -- literally, the ability to spring back.

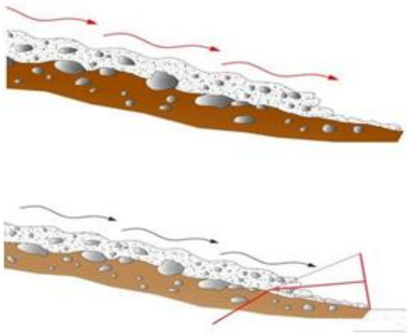

Fig 6 Flow of Avalanche

An infrastructure's resilient design aims to maintain the structural integrity while protection the occupants from the natural calamities and man-made disruptions. Resilient design for infrastructure must consider all the natural disasters to which a structure will be exposed like earthquake, extreme weather condition, heavy snowfall, temperature variation, mad made activities etc.

Understanding Existing Topographical Condition: Consideration of existing soil condition is very essential for determining the resilience of structure and its sustainability. Geographical positioning of the location with LiDAR, ArcGIS helps to get better understanding of the topographical morphology, position of the location in terms of MSL also needs to be considered. Analysis of previous data pertaining to Snowfall thickness, Rainfall intensity, occurance of earth quake or other natural calamities plays major role in accessing the site condition and designing of the resilient structure.

Vulnerability Assesment of the Location: Vulnerability describes the characteristics and circumstances which make it susceptible to cause damage to livelyhood or structure under induced mechanical condition or environmental hazard. There are many aspects which defines scale of vulnerability of any location. Socio-ecconimic importance of the location, whether any important structure is present like, dam or other similar infrastructure, major roads connecting across places, human inhabitat etc. Presence of such factor which will be at a threat to disaster plays a major role in determining the type of solution which need to be provided to mitigate the issues of avalanche, rockfall or debris flow.

Design & Engineering: Post identification of soil composition, geographical parameters, accessing previous disaster report, analysing metrological data proper design of the resilient structure is formulated. Proper analysis of the design with extreme enviormental condition and induced mechanised loading should be considered while desing the integrated hybrid structure. Proper devising of facia which will receive the impact play an important role of the entire integrated structure and subsequest transfer of load to the foundation. Proper anchorage of the structutre at extreme impact loading condition need to be analysed at breaking load. Each and every member of the assemby must breaking and yeild loading configuration, joints and hinges must be properly designed easing to load transfer. Finally needs to be tested.

Based on the preliminary site visit and collected geological data, the rock type are highly weathered slate and phyllites, grayish to dark gray colored, soft in nature with overburden layer of loose grained soil about 2 to 5m of varying thickness. The slope inclination is about 60^0 to 65^0 with horizontal from existing road level. The total height of the slope is about 250-270 m and stretch length is about 220 m. It is proposed to construct an avalanche gallery which will bypass the snow mass movement or avalanche flow.

Methods of controlling the snow falls on transportation routes can be classified as either prevention or protection measures. In selecting an appropriate protection system for the particular site, the following factors need to be considered

- ➢ Snow fall heights and frequency of falls.
- ➢ Physical size of the accumulated snow.
- ➢ Slope Geometry and available space at the base of slope.
- ➢ Potential Damages
- ➢ Equipment access and available construction materials.
- ➢ Construction Cost.

Avalanche galleries are usually constructed where there is a gradient issue.

➢ Gentle slopes: with an incline below about 30°.

➢ Steep slopes: with an incline over 30°.

➢ Very steep slopes: with an incline over 35°.

➢ Extreme steep slopes: extreme in terms of the incline (over 40°), the terrain profile, proximity of the ridge, smoothness of underlying ground. So the steep slope that is frequently source of snow fall.

The existing road width consists of single lane configuration which has to be widened first for converting it into 2-lane highway. For such requirement, the existing hill profile has to be excavated further into a stable slope mass to obtain a road width of approx. 13m. The proposed gallery shall consist of a roof structure with approx. 6 m along the valley side, approx. 8.5 m along the hill side with a column supported structure along the median of resulting highway.

Design & Engineering: The static and dynamic loading on road protection galleries can be of different types. Whereas galleries to protect against rock falls are subjected mainly to concentrated forces from falling rocks, avalanches produce mainly compressive and tensile forces as the avalanche flows over the gallery, together with large static loadings due to the snow which remains. Both of these force

Systems can be economically resisted by anchoring the galleries into the rock by post-tensioned anchors.

In the design of a gallery, two mutually contradictory requirements must be considered: On the one hand the large loadings call for a large number of support points (if possible also on the downhill side), but on the other hand a «forest of columns» is undesirable for optical and aesthetic reasons and indeed in many cases a support on the downhill side must be avoided altogether, on account of the geometrical und geological circumstances.

Proposed Location and Site: Changla Pass is the mountain pass located in the desert land of Ladakh, at an altitude of 17,590 ft above sea level in the Ladakh Ranges between Leh and the Shyok River valley. It is one of the highest motor-able road in the world.

Changla Pass is also a part of silk route, it gained fame after Jurassic ammonoids were found here making it ecologically and historically important. The pass is 15-km long and the roads are absolutely steep. Unlike other passes in the Himalayas, due to border disputes with China, Changla Pass is maintained by Indian Army. With the latest incidents of disaster triggered by massive avalanche which took life of several army personnel and made many civilian stranded at 2km short of Chang La and with Indian Army's involvement 73 of them could be rescued. After this incident, initiative was taken up by Indian Army to mitigate the issue of seasonal avalanche and road blockage.

Fig 7: Google Earth Image of site Location (a)

Topographical survey was carried out along with Ariel survey to identify critically disaster prone zone.

Fig 8: Google Earth Image of site Location (b)

After the Ariel survey, critical sites were identified and detailed topographical survey was carried out.

Fig 9: *Site Location (I)*

Executi on of Trial Plan: Resilience structure post design and engineering in accordance to the Structure’s criticality, vulnerability to damage, execution of trial plans to be drafted accordingly. Particular care needs to be considered during driving of piles or anchors for foundation and erection of the othe panel member and synchronising with proper joints and coulpling system.nano-capsule induction and installtion of sensors. Post completion of trial landfill mechanised induced load to be applied to *plastic limit* if the clay liner where in *breaking* point can be determined and how effectively self sealing capsules are performing at that level needs to be analysed and tabulated at various environmental, phsical and chemical condition.

Fig 10: Site Location (II)

Monitor & Evaluate: Proper monitoring of the system will eneble proper functioning, evaluation of the primary data. Regular checking of the integrated sensor system, clay liner layer, periodical site inspection to detect any possible chemical attack at site, any leakage of gas are needed to be checked and tabulated in addition to automated data collected for evaluation of the system implemented.

Analysis of Data: Periodical review of strategies adopted based on the primary and secondary integrated data is essential and any changes in the strategies based on the alteration in the parameters obtained needs to be impemented. As landfill is exposed to volatile phisio-environmental condition, periodical review of the stretigies are of outmost importance based on the actual in-situ status. Post analysis of data feedback to be feed to the design engineering and subsequent trial plan.

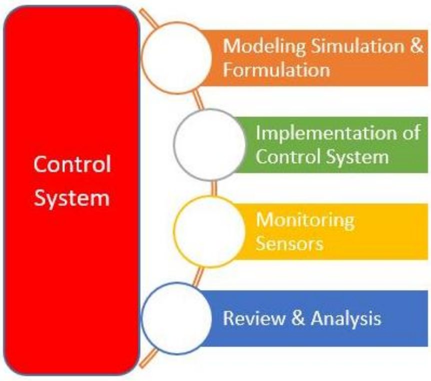

***Fig 11:** Research Methodology*

II. RESULT & DISCUSSION

Key Findings of Post site assessment

≈ Slope angle varies from 30 degrees to 40 degrees.

≈ Thickness of Snow is about 5-7m from the Road Level

≈ Low level Temperatures have been recorded even during summer Season

≈ Workability along the locations at location 2 and 3 would be easier.

≈ Dry Snow & wet snow with debris makes the sites prone to disaster.

With all these parameters and constrains design was carried out for the site and the solution proposed was Avalanche Shed with pre-fabricated concrete panels anchored to ground with micro-piles and ground anchors.

Schematic Sketch:

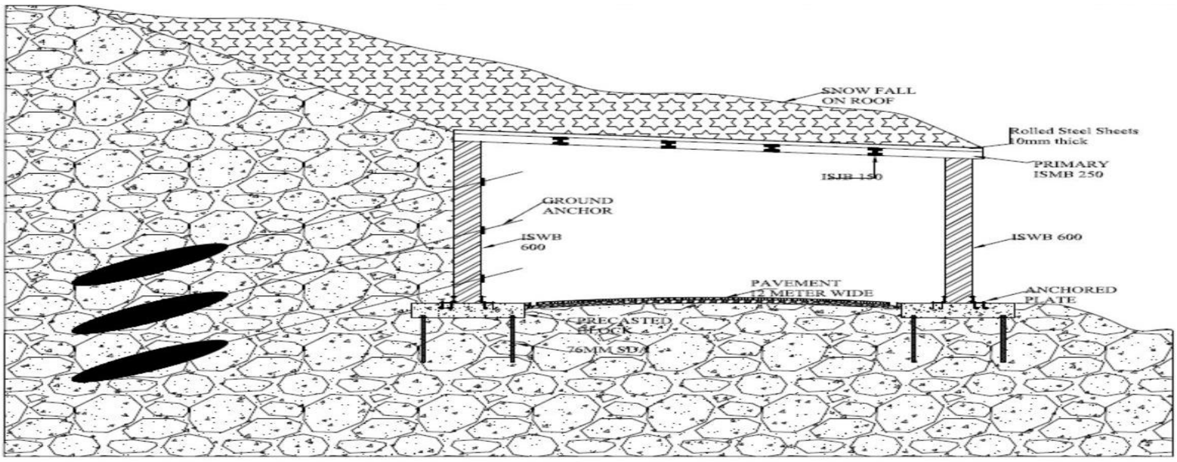

Fig 12: Schematic Design (A)

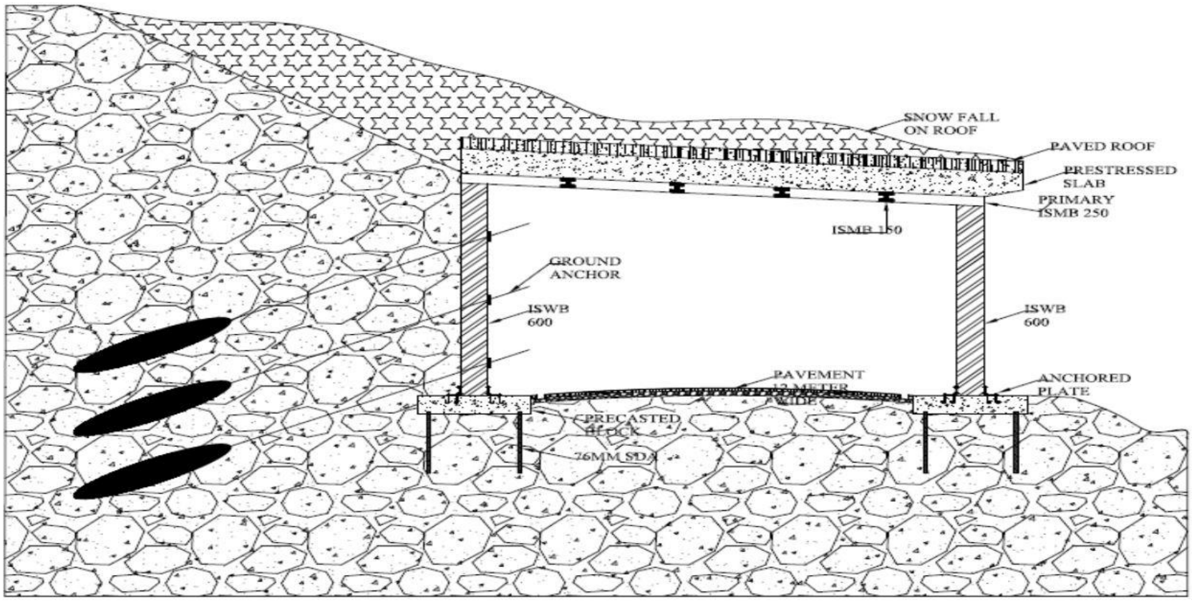

Fig 13: Schematic Design (B)

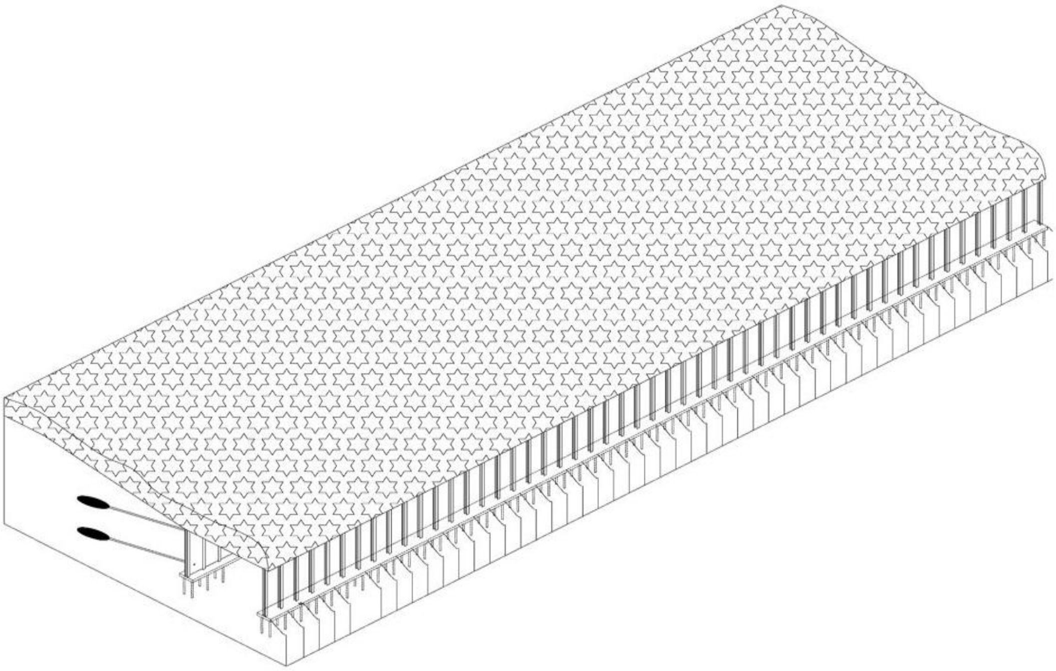

Fig 14: Isometric View of Shed Tunnel

Fig 15: Proposing Prototype Image at Location

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