RAPIDLY DEPLOYABLE STRUCTURES FOR THE TOURISM INDUSTRY IN SRI LANKA

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Abstract: This research involves the concept of creating rapidly deployable ecofriendly cabanas for the tourism industry in Sri Lanka. The cabanas are to be pre-fabricated; thus could be purchased off the shelf and assembled at site. The tourism Industry in Sri Lanka has witnessed rapid growth since May 2009 and the concept of deployable structures could benefit largely in improving the accommodation facilities in the country.

The primary objective of this research is to conceptualize the design of a structure such that it could be dismantled within three days and re-assembled within three days without the use of any heavy machinery. The structure is expected to be eco-friendly, and energy efficient. Furthermore all elements of the structure could be transported by a single container. This research explains the potential advantages of having deployable structures in Sri Lanka's tourism industry such as speedy construction, transportability, reusability, low initial investment, instant cash flows, promoting the concept of effective and efficient land use and ecofriendly tourism. In addition important considerations such as membrane selection, floor truss arrangement, footing arrangement, arched beams as well as sustainability are also discussed.

This research finally analyses a real life example of a deployable structure for the tourism industry and the content of this research includes primarily the knowledge gathered during the design phase of this project. This research is presented with the sole intention of disseminating information that would be considered useful in such future projects that could uplift and enhance the tourism industry in Sri Lanka.

Keywords: Rapidly Deployable Structures, Sri Lanka Tourism

1. Introduction

Deployable structures are structures that can be easily reduced in size for transportation or storage. A number of everyday structures could be classed as deployable; tents and umbrellas are two simple examples. (Guest S. , 1994)

There are many historical and modern applications of deployable structures in the world. Historical applications of deployable structures can be identified as the Mongolia yurts, the velum of the Roman Coliseum and Da Vinci's umbrella. In the modern day, the use of deployable structures is most commonly observed in the field of space applications because of the significantly large structures that would have to be transported to space in launch vehicles which are limited in size.

Deployable structures can be categorized primarily under two main categories as fully deployable structures, that do not involve the assembling of components and fully demountable structures that are stored as separate components and assembled at site. It must be noted that the concept proposed in this research paper involves a fully demountable arch supported tensioned membrane type deployable structure.

The introduction of deployable structures to Sri Lanka's tourism industry is expected to largely benefit the industry in terms of diversifying its tourism product portfolio and also help satisfy the forecasted demand of 2.5 million tourists annually, by the year 2016 according to reports issued by the Ministry of Economic Development, Sri Lanka. (Ministry of Economic Development, 2010)

2. Proposed Concept

The concept proposed in this research paper involves the design and development of a rapidly deployable eco-friendly structure for the tourism industry in Sri Lanka. The structure is to be pre-fabricated and could be purchased as an off the shelf product and assembled at site. This proposed structure was created with the intention of satisfying the following primary objectives,

1. It could be dismantled within three days and re-assembled within three days without the use of any heavy machinery such as cranes
2. All equipment belonging to the structure including its furniture and all other interior elements could be transported in one single container
3. It is eco-friendly and energy efficient

2.1 Concept Description

The proposed structural concept will comprise arched beams of varying sizes to provide a unique shell type structure. A shell type structure has been selected as it has been historically identified as the most efficient structure in terms of its structural integrity; while it is also an easy structure to be assembled due to the minimization of joints unlike in a box type column-beam structure. Furthermore a shell type shape would also eliminate the need to provide columns within the structure. The arched beams would support the entire roofing membrane without the need to provide columns as support. There is no need to provide walls since the arched shape would act as the walls of the structure as well. (See Figure 1)

These arched beams will be covered with an external membrane (fabric) that would act as the roofing and walling material. The proposed concept will also comprise an internal membrane as an aesthetic requirement. This internal membrane will be equivalent to a ceiling as seen from inside the structure. It must be noted here that both the internal and external membrane will be pre-tensioned in order to avoid flapping of the fabric.

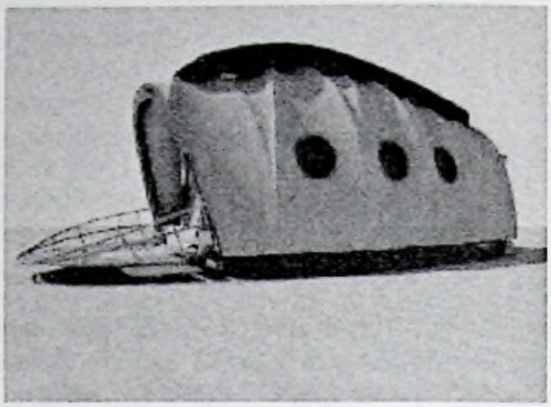

Figure 1: Proposed Concept

The floor panels will be constructed with timber due to its light weight and as part of the sustainability aspect of the proposed concept. The floor panels will be supported by a steel space truss at the bottom. This steel truss would be constructed in a manner where it could be easily dismantled into several components in order to facilitate the concept of deployability. The loads from the roof beams and the floor truss will be directly transferred to the ground by a pad type foundation.

A retractable cover would be provided at one end of the proposed structure and this would act as the entrance to the structure which can be opened and closed as required. In addition circular openings will also be provided on the side of the structure in order to ensure that the structure is sufficiently ventilated.

A cantilevered slab section is provided on one side of the structure and this would act as a verandah/balcony like area for its occupants. It is proposed that if required a swimming pool could be constructed if the structure is installed as a permanent structure for a reasonably longer duration. (The swimming pool constructed here would be no different to a conventional swimming pool as it would be installed as a permanent structure)

The load transfer of this proposed concept will be as depicted in Figure 2.

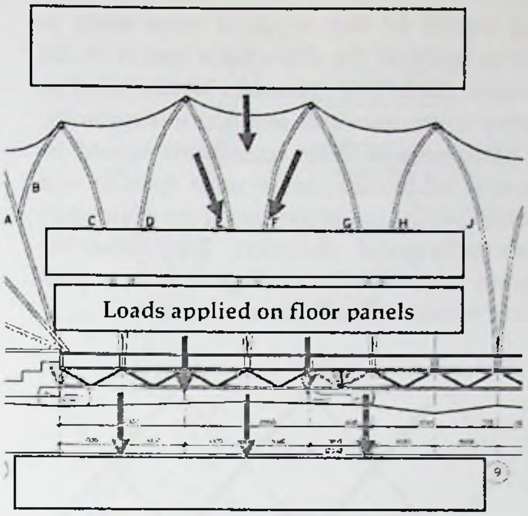

Figure 2: Load transfer on the structure

2.2 Advantages of this project

The advantages of this deployable cabana like structure to Sri Lanka's tourism industry can be explained under the following criteria.

-Speedy Construction:
This project once developed could be simply purchased off the shelf as it would be pre-fabricated. The structure would be produced in large numbers and there by many procedures such as the sizing of members, membrane sizing, platform design etc could be automated at the manufacturing plant. The manufacturing plant is thus expected to obtain economies of scale benefits with time, as a result of the learning curve effect and also the continuous repetition of the same task a number of times.

-Transportability and Reusability:
Rapidly deployable structures of this nature are expected to reduce the ineffective use of resources since it is possible to transport the structures from one location to another based on peaks and troughs in tourist demand.

-Low Initial Investment:
A structure of this nature doesn't require the acquisition of large plots of land as a one off purchase, avoids overhead costs in terms of head office expenses, project managers salaries, administration costs etc. The initial investment is thus relatively low in the case of this prefabricated structure as opposed to a conventional structure constructed at site.

-Instant cash inflows:
A prefabricated structure can readily generate cash inflows as soon as it is erected at site as opposed to conventional hotels that usually consume 2 to 3 years (or even more) as its construction period during which no cash inflows are generated. This instant ability to generate cash inflows can be used to attract investors in investing in the tourism sector of the country.

-Promotes the concept of effective and efficient land use:
Land owners are reluctant to sell their entire plot of land as a one off sale since there is a natural preference to preserve land as a long term asset unless there is an urgent need for cash flow. This results in large amounts of idling, unutilized or underutilized land in the country. The ability of this deployable structure to be transported from one location to another however ensures that there is no need for one off acquisitions of land. Leased out plots of land for shorter time durations are preferred instead. This would ensure that landowners willingly lease out their land for shorter time durations thereby ensuring the efficient and effective land use towards the tourism sector.

-Promotes eco-friendly and sustainable tourism:
Eco tourism is facilitated by such deployable structures as they can be erected by using natural topographies thereby with the least damage to existing land conditions. Furthermore many green features such as the use of solar energy, recyclable and renewable material, rain water harvesting, daylighting, occupancy sensors as well as LED lighting are also incorporated in this structure.

3. Design Considerations and Alternatives

3.1 Choice of membrane selection

Notes to Table 1:
*Properties such as Flexibility, Sound Proofing, Resistance to varying climatic conditions and maintenance have been evaluated qualitatively based on some of the applications of each type of material.
**Colour availability has been evaluated based on company brochures that have been issued for each material type.

***Greenguard certification - The Greenguard Environmental Institute (GEI) and Greenguard Certification is broadly recognized and accepted by sustainable building programs and building codes worldwide.

The membrane forms a critical part of the proposed project as it would provide covering and shelter to the structure. Parameters such as lightness, flexibility, colour, flame retardancy, sound proofing, strength, resistance to varying climatic conditions, maintenance and recyclability must be given special consideration. Table 1 represents a comparison of 4 different types of membrane materials considered.

Table 1: Summary analysis of suitable membrane material

Commercial Name of Membrane		Ferrari 6002	Precontraint 502	Versei-dag PTFE	Batyli-ne AW
Lightness (g/m2)		630	590	800	600
Flexibility*		High	High	High	High
Colour Availability**		High	Very High	High	High
Flame Retardancy		BI/DIN 4102	BI/DIN 4102	A2/DIN4102	BI/DI N 4102
Sound proofing*		Good	Good	Good	Good
Strength in N/5cm (warp/weft)	Tensile Strength	2500/2500	2500/2500	4200/4000	2500/2500
	Tear Strength	200/200	250/200	300/300	250/250
	Adhesion	80/80	90/90	60/60	Not Available
Resistance to varying climatic conditions*		Good, high UV resistance	Good, Very high UV resistance	Good	Very Good
Maintenance*		Good	Good	Good	Good
Recyclable		***Green guard certified	100% recyclable	Good	100% recyclable

3.2 Floor Truss Arrangement

There would be two types of truss units in order to facilitate the deployable nature of the structure. These two types can be identified as primary truss units and secondary truss units. The placement of these truss units would be such that all primary truss units span in one direction whilst the secondary truss units span in an orthogonal direction. The following diagram illustrates this. (Figure 3 is a plan view of how the truss units are placed)

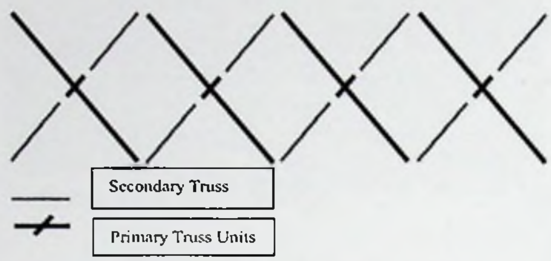

Figure 3: Placement of Primary and Secondary truss units

As shown in Figure 4 there are two types of joints that will have to be provided given the nature of this structure. They are,

- Primary Truss Unit and Secondary Truss Unit Joint
- Truss Unit and Footing Joint

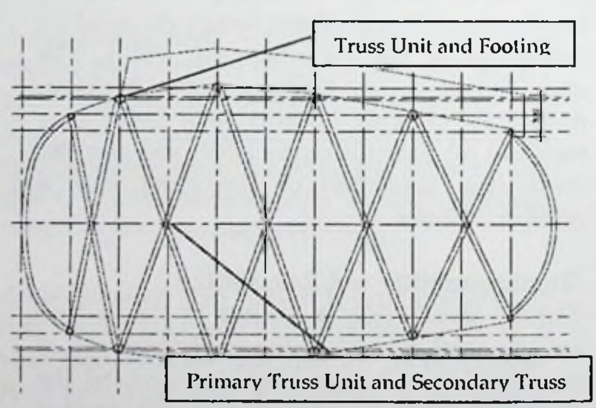

Figure 4: Connections/Joints belonging to the structure

Figure 5 shows the Primary Truss Unit and Secondary Truss Unit Joint and Figure 6 shows the Truss unit to Footing Joint.

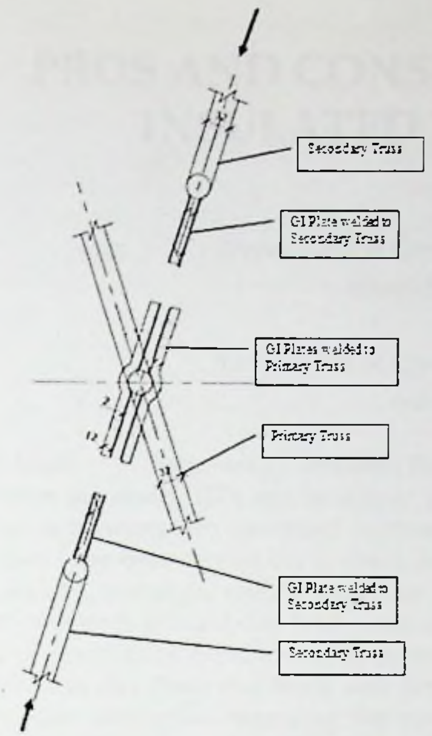

Figure 5: Primary and Secondary truss unit joint before connection

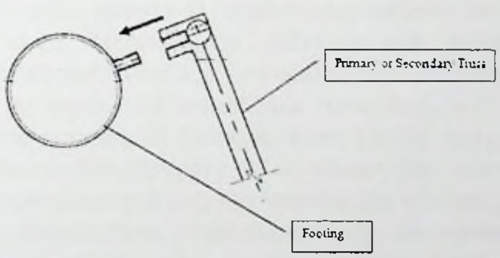

Figure 6: Truss Unit to Footing Joint before connection

3.3 Footing Arrangement

As shown in Figure 7, the load transferred through the arched beams and also the floor truss will be taken to the ground through solid footings which will be placed at points where the arched beams meet each other at the bottom of the deployable structure.

The footings can be designed using circular tubes and then connected to a square pad such that the loads are safely transferred to the ground. It must be noted that this square pad would not be part of the deployable structure and an element that would have to be constructed of concrete by the client before the deployable structure is erected.

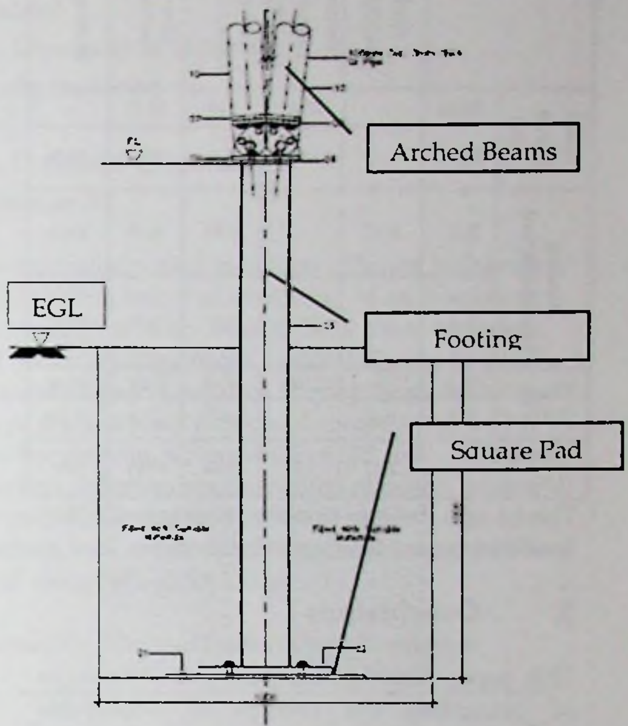

Figure 7: Sectional view of a footing arrangement

4. A Real Life Case Study on Deployable Structures for the Tourism Industry

The membrane stresses were evaluated by outsourcing it to an engineering company specialized in the field of membrane analysis. The membrane stresses as obtained from the report issued by them was then reincorporated in to the SAP model as point loads on the frame structure by using pre-stressed tendons.

4kN/m^2 and 2kN/m^2 were considered as the design dead and imposed load respectively for the floor panels whilst 0.6kN/m^2, 0.25kN/m^2 and 1.187kN/m^2 were considered as the design dead, imposed and wind load respectively for the arched beams. (Refer section2-Proposed Concept). The analysis results obtained were as shown in Table 2.

Table 1: Summary of analysis results

		Arched Beams (φ=100mm, t=4mm)	Beams at bottom connecting arches (φ=100mm, t=4mm)	Floor Truss - Top and Bottom Chords (φ=32mm, t=4mm)	Floor Truss - Web members (φ=25mm, t=3mm)	Footings (φ=150mm, t=4.5mm)
Axial Force (kN)	Max	-	27.93	135	37.73	-
	Min	-	-60.83	-145	-32.62	-98.79
Bending Moment (kNm)	2-2	11.37	-	5.89	0.49	23.06
	3-3	-	19.95	0.25	0.25	29.57
Shear (kN)	2-2	-	19.05	0.19	2.57	63.44
	3-3	9.63	-	10.36	1.92	91.52
Torsion (kNm)		2.17	1.37	0.34	0.10	0.81

The (-) sign denotes that the value is negligibly small compared to other values.

5. Conclusions

This paper describes the potential advantages of promoting the concept of deployable structures for Sri Lanka's tourism industry as speedy construction, transportability, reusability, low initial investment, instant cash flows, promoting the concept of effective and efficient land use, ecofriendly tourism, sustainability etc. These advantages are expected to benefit Sri Lanka's tourism industry largely in enabling it to meet the forecasted demand of 2.5 million tourists annually, by the year 2016. Furthermore important aspects of consideration such as the selection of a suitable membrane material, floor truss arrangement, footing arrangement, have also been discussed in detail. The last segment of this paper describes the results obtained following the modeling and analysis of a real life case study on deployable structures for Sri Lanka's tourism industry.

References

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