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DETAILS FOR ANCHORING AND MOVING OF SMALL AND MEDIUM SIZED RETRACTABLE MEMBRANE ROOF STRUCTURES EXEMPLIFIED WITH REALISED PROJECTS

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Summary: The paper discusses technical solutions that represent a practical technical input in the construction of sizable retractable roofs, which will result in a positive economical relationship between the involved costs of the site amendments and the area to be covered.

1 INTRODUCTION

Retractable membrane constructions offer an economical solution to weather disturbances at open air venues. The involved technical requirements are more complex when compared with stationary installed membrane roofs. Indeed, several mechanical components are required in order to move the roof in a comfortable way. These constitutes of railways or a rope system on which the rooftop can be relocated along. Furthermore, the systems can be utilized for load bearing during the spanned state. Equally, a well-designed driving mechanism is mandatory to move the membrane between the parking and moving position. The last part of the driving process includes spanning and anchoring of the membrane, will be executed by high-specialised machines with a complex mechanism. Correspondingly, the described technical effort is extremely meaningful in terms of savings on a stadium roof. In order to deliver a cost-efficient solution for small and medium-sized roof constructions, the design of the power unit and details of the functional membrane expresses an effective parameter.

2 CONSTRUCTION ELEMENTS

2.1 Slide bearings

The procedures that are applied to connect membranes to cable driving system are punctual placed hangers. A proven way to minimise the required forces for moving a membrane roof is the usage of a cable pulley system with a very low rolling resistance, which is comparable to a cableway. Because of the involved multiple high forces during its usage, the permitted lateral pressure between cable and pulley could be exceeded. The only remedy to this problem is to increase the pressure area by using several but smaller pulleys or a slide bearing. This kind of bearing has the disadvantage of having a higher slide friction resistance when moving the roof.

If the movement of the slide bearing occurs as a case of tension forces from the membrane, it results according to the direction of action in a tension force component along the cable and a vertical force component which in turn results in a friction force contrary directed to the tension force (Figure 1). If there are small angles between the hangers and the direction of movement, the occurring friction force can be effectively handled. This is the case, if the slide bearing and the membrane are closely spaced. Due to the diverged geometry of the ropes and the membrane, there is very often the need of hanger elements. If the slide bearings are moved by the membrane under these geometrical conditions, a self-blocking system is in place due to the inauspicious angle.

In the past, solutions have been adopted where a motor has separately operated every single hanging point. The more devices used in the construction, the higher the costs for purchase, maintenance, control system and power supply is. An improved concept is the motorisation of single cable axis where a revolving reef cable moves the hanging points.

It is often the case that the reef cable drives only one hanger and the membrane itself indirectly moves all other hangers. By using a direct interlinking of all slide bearings, undesirable deviation forces – and hence the resulting friction – can be eliminated from the system. Thus the membrane area will be effectively freed from the employed forces and the effect of higher friction on the slide bearings will be minimised so that, from a technical point of view, the application of slide bearings is possible.

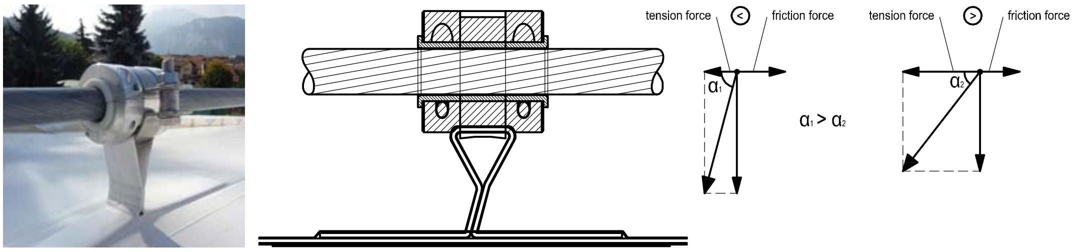

Figure 1: forces in the hanger system

2.2 Central Motor Unit

By activating several cable axes with one central motor unit, and through technical components and the control system, it is possible to further reduce the effort required. For big circular roof constructions it is very common to separate the motor devices for each radial rope axis and to place them because of their size circumferential. For smaller roofs there is also the possibility to conduct all reef cables to a central located cable drum. This offers the application of a central motor unit. The single cable drums needed for all the reef cables are stapled and mounted on a vertical aligned drive axle. This patented system is applicable for both radial and parallel driven roofs. By varying the diameters of the cable drums, it is possible to react to different driving length as unsymmetrical roof design. With this simple mechanical coupling, no further sensors or control system will be required. All corner plates of the membrane roof reach in by operating this way with a reliable precision their end position at the same time.

2.3 Anchoring

For small and medium sized membrane roofs it is feasible, through the driving system, to achieve the essential pre-tensioning of the membrane. At the same time, under certain boundary conditions, the lever and deviation effects can be utilised. When in position, the use of the anchorage of the membrane roof to carry the static loads from external forces is frequently provided by electrically or electromechanically driven locking devices in combination with a gripping mechanism. Since combined systems for driving and locking were often used for big retractable roofs, their placement along the circumferential border becomes mandatory. Due to the clearly smaller acting forces of the membrane for small and medium sized roofs the omission of a gripping device there is a need for a very compact anchoring device.

Technically, this could be provided by operating an autonomous mechanical locking and unlocking clamping system (Figure 2). While the system is working in a mechanical manner, it is possible to disclaim active actuators and related power- and control wires. However, radio controlled sensors give a status request for the anchoring. The stated condition is transmitted to the control device of the roof in order to have the lock on the anchorage at every time.

Figure 2: autonomous mechanical clamping system

2.4 Parking position

Conventionally the parking position of big circular Roofs is located in the centre. For linear moveable roofs the parking position is positioned either at two opposite sides or only at one side. In the parking position the membrane is packed compact as possible. The single fields of the whole membrane will hang down in a regular manner. In this situation, the membrane has must be protected from weathering because of the directly generating of ponds in the local bottoms. The collected water cannot drain off; an overload situation probable results in a catastrophic failure of the roof structure. Due to this reason, it is necessary to protect a parked retractable membrane roof with a secondary roof structure from weathering.

One possible solution to meet the requirements with a minimum effort is to integrate the secondary roof structure as far as possible in the primary roof structure. For instance, by supplying the single bearing axes of a linear moveable system with roof segments which overlaps in the parking position similar to the Scale armour of an armadillo. Every single roof segment has a separate drainage available which enables a direct dewatering. Small roof segments allow the use of transparent acrylic glass elements. This approach is profitable, where the erection of a secondary roof is too expensive due to an exposed position of the roof structure.

3 CASE STUDIES

3.2 Courtyard roof – Künstlerhaus München

The courtyard roof of the “Künstlerhaus” in Munich represents with a membrane area of 200m^2 a comparable small roof structure. With up to six punctual hangers on every cable and border axes the membrane with the shape of a quadrant are linked to the total of four cable axes and two border rails. For parking the roof will be moved to the centre of the radial aligned cables located in the northwest edge of the courtyard. The mounted hood is integrated with a central motor unit, which drives the quadrant aligned cable drums of the reef cables with a link chain. The different driving lengths of the cable axes are compensated by varying diameters of the cable drums. The compact cylindrical shaped slide bearings are constructed as an aluminium swivel integrated with a plastic inlay with a very low friction coefficient (Figure 3). The slide bearings will be moved with thin separate cables aligned parallel to the bearing cables and connected to the driven corner plates of the membrane. Thereby the slide bearings can be reliably positioned with a minimum expenditure of energy despite the strong varying length of hangers. The anchoring of the spanned membrane area will be accomplished by snapping of two clamps for each cable axes. The hooks enable to bear the static wind loads from the membrane to the strut. In order to move the membrane back to the parking position, it is necessary to overstretch the membrane with the objective of opening the clamps reliable with a spring mechanism (Figure 2).

Figure 3: slide bearings with positioning and reef cables

3.3 Dome roof – Tree Top Path Bad Harzburg

The dome roof of a 24m high-located platform of a tree top path in Bad Harzburg will be moved with a central motor unit along the eight radial aligned axes of the existing steel structure. For this project, the cable drums are stapled in the vertical axes so that the radial incoming reef cables directly can run on the cable drum. The appropriate height of touching of the reef cables on the single drums will be controlled by pulleys.

3.4 Auditory roof – NaturTheater Bad Elster

For the auditory roof of the “NaturTheater” in Bad Elster linear movable arches will be supported by two 7m high lateral placed elevated tracks. The auditorium is stretched with a rate of 2:1. With a width of 25 metres, the place will be spanned with arches made out of tubular steel sections covered with a saddle shaped membrane. During parking position, the membrane hangs between the narrow placed arches so that a hood is necessary to avoid ponding. For such exposed structure, a secondary roof structure is conjunct with high effort and costs. For this reason minimal invasive solution is chosen by creating a light and unremarkable hood made out of short cantilevers with acrylic glass elements on each arch. In the parking position, the single roof stripes will close to a complete area similar to the scale armour of an armadillo. Due to the light slope of the acrylic roof to the arch, the gutter on the arch will secure the drainage of the water. Certainly, the rain gutters that are located on the elevated tracks will drain the collected water.

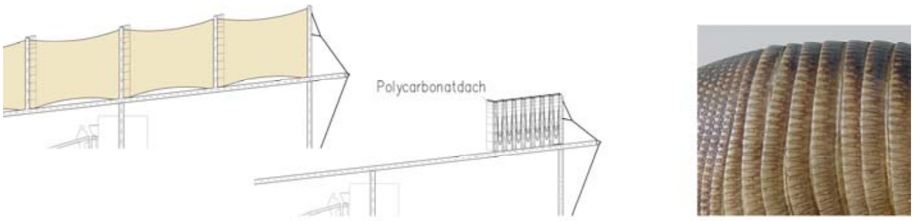

Figure 4: secondary roof structure to protect parked roof from weathering

4 CONCLUSIONS

The above-discussed methods on the three case study projects represent a justifiable technical input in the construction of retractable roofs of the considered dimensions that, in turn, results in a positive economical relationship between the costs involved and the area to be covered.

REFERENCES

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