A REVIEW PAPER ON DIFFERENT TYPES OF SELF SUPPORTING ROOF

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Abstract : Any building structure used by the industry to store raw materials or for manufacturing the products like machine/s is known as an industrial building. Industrial buildings may be categorized as Normal type industrial buildings and Special type industrial buildings. Normal types of industrial buildings are shed type buildings with simple roof structures on open frames. These buildings are used for workshop, warehouses etc. These building require large and clear areas un-obstructed by the columns. The large floor area provides sufficient flexibility and facilitates the later changes in the production layout without major building alterations. The industrial buildings are constructed with adequate headroom for the use of an overhead traveling crane. Special types of industrial buildings are steel mill buildings used for manufacture of heavy machines, production of power etc. The function of the industrial building dictates the degree of sophistication.

Keywords- Truss, Hollow Pipe, Tubular Pipe, GI Sheet

I. INTRODUCTION

The roofs are not only to protect the structure and its internal element but they also give an aesthetic view to the structure. As the roof occupies a very huge area and consumes large amounts of material for its construction, optimal design of such a structure is of utmost importance. The earlier research on the roof structures was mainly concentrated on the geometric design of the roof structure, giving less or no significance to the structural engineering aspect. But once the financial implications associated with roof system is confronted, the need for economical structural system is fully realized. With the invention of self-supporting structural elements as roof covering, it is now possible to develop innovative shapes of roofs especially for industrial, sports & other service buildings and public areas where long spans are desirable.

In this paper, a brief review of a few retractable roof stadiums constructed in different parts of the world is also presented. Similarly, with regard to structural optimization, genetic algorithms are found to be more appropriate in the present study.

II. LITERATURE REVIEW

(Kassabian,et al, 1999) had presented a new concept for geometrical design of roof structures. According to his study, the structures consist of a foldable lattice beams connected by cylindrical joints, to which covering panels or membranes are attached. These structures fold towards their perimeter and there are practically no restrictions to the shape that can be adopted. Solutions to the key problems that have to be solved in the course of the kinematic design of this new type of structure were presented, including two different ways of connecting them to fixed foundation points while maintaining their internal degrees of mobility, and how to determine the shapes of the covering panels to avoid interference during retraction. A preliminary study of the gravity induced deflections of the type of structure described in this paper, including simulations with the finite-element package ABAQUS and experiments on a physical model were carried out. The study showed that this type of structure behaved in a way similar to a grillage of beams connected by moment less joints. The gravity-induced deflections vary during the expansion of the structure, as each beam is subject to twisting moments of increasing magnitude as it rotates towards the centre. Thus, the innermost points of the structure deflect downwards. Once the structure is fully expanded, various strategies can be adopted to make it secure under operational loads. For example, some of the joints can be latched, or the deployment actuators can be driven beyond the point of first ‘collision’, in order to preload the whole structure and remove the backlash from the joints.

(Thomas Buhl, Jensen et al, 2001) presented the optimal shape of cover plates for circular ,symmetric retractable roof structures based on a grid of multi-angulated rods connected by revolute joints. It was assumed that these cover plates are co-planar, and hence they are not allowed to overlap in any configuration; they are also required to form a gap free surface in the closed configuration. Suitable shapes for the plates are found by formulating an optimization problem based on suitably defined overlap and gap area functions. The size of the hinges of the bar structure is considered in the optimization. To stabilize the optimization convergence various move limit strategies are tested and a min-max formulation was proposed. The optimization problems were solved by the method of moving asymptotes and the sensitivities are found by finite differences. A series of test 9 cases were presented, whose results agree with previously known solutions, however the generality of the present method makes it suitable to develop structures of general shape.

(Noémi Friedman and GyörgyFarkas, 2011) have focused on review of roof structures that are movable either for enabling quick and/or safe construction or in order to adapt the structure to external excitations. Roof designs coming from both motives were discussed. After a short review on historical background an extensive overview was given on different types of transformable roof structures, namely retractable roofs with rigidly moving parts, retractable/deployable pantograph structures, the pantadome erection, deployable tensegrity structures, retractable/deployable membrane structures, pneumatic structures and constructional methods of concrete shell structures were presented. Early transformable designs appeared in first place for housing sport venues. With the currently growing media focus on sport events, the demand for retractable structures is steadily increasing. Most of these designs use rigid moving parts to retract the roof structure. In most of the situations the slicing of an ideal roof shape results in gigantic structural heights. Mechanical instruments enabling retraction increases the costs of the structures further.

On structural aspects pertaining to roof structure very few research papers are available as on date. A review of existing retractable roof structures constructed in various parts of the world is presented here.

Rogers Centre

Rogers Centre is the first full-scale roof stadium of the world. It is located in Toronto, Ontario, Canada and the construction was completed in 1989 with a cost of about C$578 million. Then called as Sky dome, but since renamed the Rogers Centre. The stadium was designed by local architect Rod Robbie, the structural engineer was Mike Allen and developed by Bill Neish and RAN consortium. The roof rises to a height of 310 10 feet with a span of about 700 feet and has a seating capacity of nearly 50,000 spectators.

The roof is a massive steel structure weighing 22,000,000 pounds, consists of four panels, the larger one is stationary and the other three are moveable. The last panel rotates 180 degrees to completely close the stadium. The roof is linked to wheeled bogies that roll by electrically driven train engines with the tracks supported on concrete superstructure and takes 15 to 20 minutes to open or close.

Bank One Ballpark

Bank One Ballpark is the first retractable roof stadium in United States located at Phoenix, Arizona. Desert climate of Arizona necessitated having an air-conditioned retractable roof stadium. The stadium was designed by Ellerbe Becket and was completed in 1998 at a cost of $354 million of which $70 million is for retractable roof and has a seating capacity of about 49,000 spectators. It was developed by the contractors Schuff Steel Company and was renamed as Chase Field in the year 2005. The roof rises to 200 feet height and spans 517 feet with 6900 ton roof weight. The roof of the stadium consists of two telescoping sections that bi-part over the middle of the playing field. Each telescoping section comprises one stationary and three moving panels; when the roof is open the movable panels rest above the stationary one. The retractable mechanism constitutes wheels at the ends of the panels resting on rails and two 200hp motors engaging four miles of steel cable to retract the roof like a drawbridge so that the roof is opened or closed in about four minutes.

Safeco Field

Safeco Field is a baseball stadium located in Seattle, Washington and was opened in 1999.It was built at a cost of $517 million of which roof costs $67 million and mechanism costs $14 million. The stadium was designed by architect NBBJ of Seattle and has a seating capacity of 47,878 spectators. The roof system constitutes three moving panels with a span of 600 feet and the middle panel rises to a height of 275 feet. The other two panels roll beneath the middle panel and all the three panels move to the east side of the stadium. The panels are pulled by cables to open or close the roof that weighs 11,000 ton in 20 minutes. When the roof is covered the stadium is not fully enclosed, it only covers the stadium like an umbrella so that spectators feel that they are in an open-air stadium. The open nature of stadium may cause uplift failure due wind pressure and to avoid that operable lock-down devices are used to tie down the roof towards the supporting structure. Each panel of the roof is provided with 18-inch dampers to prevent seismic failure. The huge weight of the roof causes enormous stresses on the wheels that slide onthe rails. To lower the stresses in the wheels pivot- beam suspension with large number of wheels is employed. The transporter assembly of the roof system is about 20 feet deep.

Miller Park

Miller Park is a ballpark located in Milwaukee, Wisconsin and the construction was completed in 2001 with a cost of $400 million. The stadium was designed by NBBJ and Eppsetin Uhen Architects in collaboration with HKS, Inc., and the contractors were from Mitsubishi Heavy Industries of America. The roof system constitutes fan arrangement of seven panels with a span of 600 feet and rises to a height of 330 feet, which pivot from a point to move along a semi-circular track. Three of the panels slide over a fixed panel on the left and two panels slide over a fixed panel on the right field side. Each panel slides along a steel rail on a pair of two-wheeled bogies.
The unconventional fan-shaped roof has met with complications; major elements of the pivot system behind home plate and the outfield roof track have been replaced. At the end of 2006 season, the roof's bogie system was replaced at a cost of over $13 million.

Reliant Stadium

Reliant stadium is the first NFL stadium to have retractable roof and is opened in the year 2002. The stadium was designed by architects HOK Sport (Populous since 2009), the structural engineers were Walter P Moore Engineers and Consultants, and the roof mechanism was developed by Uni-Systems. The roof system consists of two large panels with a span of 385 feet and 245 feet width that bi-part the field. Each panel contains five tapered depth tri-chord trusses each of 30 feet deep rolls along conventional rail assembly using just 20 wheels and 40-5hp motors and roof can be opened or closed in 10 minutes. Transporter assembly is less substantial than other retractable roofs since the roof is much lighter at a little over 1,000 tons. Roof weight is less but supporting structure compensates with daunting dimensions. Rails on which the panels roll are ultimately carried by two super trusses, which span 650 feet inside the stadium and an additional 167 feet beyond the ends to support the open roof. The light roof eliminated the need for a special wheel suspension and instead used a linked carriage suspension system. The roof itself handles wind and seismic loads with a lateral release mechanism called 4-bar linkage. The 4-bar linkage was designed to connect the ends of the trusses to the transport carriers. As the roof deflects horizontally, the bars pivot to permit this position but also continue to transfer the gravity load of the roof down through the wheels with minimal horizontal thrust at the wheel. The roof can sway up to 21.5 inches in either direction safely. This innovative solution prevented the flexibility of the structure's roof from obstructing its operation and instead created a simple mechanism with little added material.

Oita Stadium

Oita stadium is in the city of Oita in Kyushu Island in Japan. It was opened in 2001 and has a seating capacity of 43,000. It was designed by the famous architect Kisho Kurukowa and built by KT Group, Takenaka Corporation. The stadium has a retractable dome roof with roof system driven by a wire traction system. The total cost of construction of the stadium was ¥25 billion.

Toyota Stadium

Toyota stadium is a retractable roof stadium in Toyota, Japan, built in 2001 with a seating capacity of 45,000. It was designed by architect Kisho Kurokawa. The roof contains an accordion-like moving element that is operated by a system of air-pillows that enable the stadium to completely close itself.

Wembley Stadium

Wembley stadium located at Borough of Brent, London, opened in 2007, is the second largest stadium in Europe with a seating capacity of 90,000. Designed by Foster and Partneees, HOK sport, and the structural engineer was Mott MacDonald. A signature feature of the stadium is the 134 m. high Wembley arch with a span of 317 m. This the longest single span steel arcretractable roof structure in the world. The stadium was builtby Australian firm Multiplex at a cost of £798 million

III. CONCLUSION

Keeping the above points in view, following objectives are set forth for the our work

1) Development of an algorithm that integrates structural analysis and optimal structural design using STAAD Pro. Software.
2) Validation of the developed algorithm with several benchmark problems.
3) Optimal design of roof structure using the validated algorithm and STAAD Pro.

IV. REFFERENCES

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