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The material optimized design methods of sports buildings

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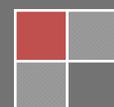
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ABSTRACT

With the large number construction of sports venues in the world, the wide variety of materials create solid structure and magnificent appearance for sports buildings, then people face the challenges of material waste, high energy consumption, inflexible functions conversion and other problems. From the view of material consumption, the optimized design method has become the key points to solve these problems in the whole life of sports architecture. This paper explores the optimized design of sports buildings which abide by the concept of sustainable development, it can take advantage of BIM and other new methods to facilitate sports buildings more optimized and refined. This paper mainly analyze the optimized design of structures and surface to achieve the goal of material saving. This paper aims to put forward some suggestions that contribute to ensure the whole life cycle of sports buildings more healthful by the material optimized design.

KEYWORDS

Sports buildings; Optimized design; Material saving; BIM.



INTRODUCTION

Facing the growing problem of energy crisis and excessive consumption of resources, people have recognized the concept of sustainable design must throughout the whole architectural life-cycle. Especially for large public architecture such as a large number of stadiums and gymnasium, they often cause serious waste of resources and materials in the process of construction and operations. These problems seriously hindered the healthy development of sports architecture and must be solved. Thus, the sports architecture design more tend to shape the suitable space with refining structure and surface. According to this kind of saving idea, the design and construction of the sports architecture can abide by the logic of rational regression, and the saving of resources and material are not only for traditional economic factors, but also profoundly promote sports buildings more healthier during their whole life cycle.

When the material saving has become the purpose of sports buildings design, it undoubtedly requires more advanced design methods. The most effective way to achieve material savings is "optimized design". Above all the word of "design" contains the "optimized" meaning, and "optimized design" is not represent the simple saving, it use rational logic and accurate way to find the most suitable constructed form for architecture. Especially for sports architecture with large-span structures and huge surface, effective material savings can become the strong support that improve life cycle of sports architecture.

THE INTEGRATION OF OPTIMIZED DESIGN AND MATERIAL SAVING

The life course of sports architecture includes the continuous stage of design, construction, operation and reuse. The most obvious solution is to improve the design method in the decision stage, the injection of sustainable "gene" in initial of the life cycle connect the sustainable development and optimized design closely. The most significance of optimized design is to compact the materials and reduce the load for the sports buildings as the "materialized form"^[1]. And, it can fully consider the materials used such as disassembly, transferable and retractable to meet the operational development and functional replacement of sports architecture. Therefore the designer will certainly closely integrate the methods of optimized design with the purpose of materials saving, to ensure the sustainable development of sports buildings.

THE NEW METHODS OF MATERIAL OPTIMIZED DESIGN

Evidently, the future of sports buildings is now with respect to optimized design regardless of structure or surface system. In this type of research and application, the material elements turning into more components and parameterization is the core innovation, the updating design software has become the most powerful tools to achieve the optimized idea. The designers identity "refining" and "optimization" firstly, and began to improve the tedious structure and false surface of sports architecture to streamlining and optimizing increasingly, even take the integration of "bones" and "skin".

In this way, through calculation and analysis of the software such as Revit and GC, the structure, facade and roof of sports buildings are divided into components unit, each unit has its code and parameters, and through continuous calculation to adjust the most appropriate scale, location and the mutual direct connection. People can easily read the data from the excel software to cooperation and modify, the professional structural engineering company and curtain wall design company also can share data, develop common design and fabricate the unit^[2]. Finally, the constantly optimize of the unit also

achieve to effectively materials saving of sports buildings, people can clearly see the technology core of optimized design is the parametric. (Figure 1)

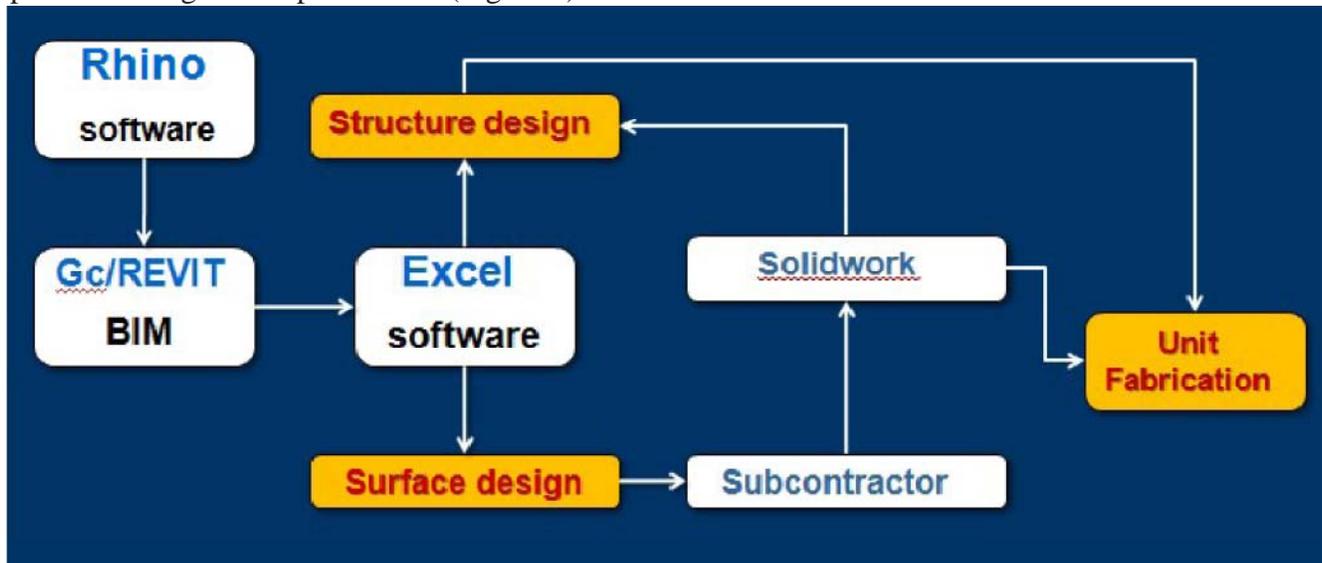


Figure 1 : The core innovation and process of the optimized design

The two aspects of optimized design methods

For the specific design of sports buildings, the architects and structural engineers need to assume two responsibilities which seems contradictory: on the one hand to implement the strategy of sustainable development, on the other hand to ensure the structural safety. The former can save materials, while the latter tend to consume more materials. Thus, optimized design is precise point of integration which can achieve functional objectives and reduce the material consumption for sports architecture. Designer has always insisted on the concept of "Preferred Choice" in a lot of engineering practice because the optimized structure must be material saving^[3]. The structure of large-span has been closely associated with the development and application of structural materials: from the concrete beam to the steel truss, from the heavy load-bearing walls to advanced bionic structures, from stone to membranes, people have been exploring and seeking more lightweight and strength materials for the optimized design of sports architecture.

For example, Bionic Engineering take inspiration from nature and provide the solid structure and wonderful forms of construction, it also as an appropriate entry point for sports architecture. The stadium in figure combine subtly the hexagonal honeycomb structure with the membranes, the designer utilize the concepts combine simple with solid to create the huge roof of the stadium. This optimized design will definitely make the roof structure refined according to the mechanical logic, meanwhile it will show the excellent physical properties of membranes.(Figure 2)

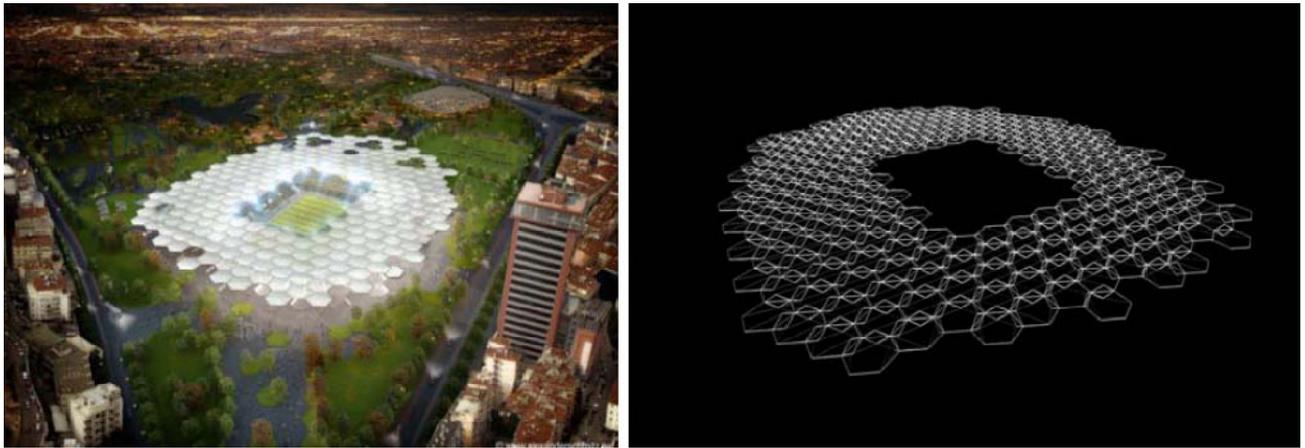


Figure 2 : Bionics is the suitable entry point for optimized design of sports buildings

The optimized design of structural system

The optimized design of sports architecture is reflected in many professional aspects such as structure selection, shape optimization etc. Above all, the large-span structure is its most special feature, it clearly shows the structural optimization is necessary to stand by the rational logic of the force transmission, further require the creative use of structural system and materials. During the long-term practice, people evaluate the large-span structure according to five indicators^[4]:

1. The strength of material gave full play to the role, increasing the rod and reduce strut in axial force component;
2. Make the reasonable design of pushing or pulling force on the bearing;
3. The manufacturing and installation costs of structure are less and saving;
4. Fourth, the advanced structural system using the relatively small amount of materials to get solid support;
5. Pay attention to structural performance which shows the rational logic and aesthetic value of the structural system.

From the five indicators, it can be summarized as follows: the material saving of structures is the basic factor of optimized design. Compared with the traditional structural design, the optimized design has more explicit metrics such as the smallest volume, the lowest cost, the minimum amount of material consumption and so on. For sports architecture, the structural optimization seeks for the most rational use of material properties, so each geometric parameter of the construction components will get the best coordination. Therefore, the optimized design of structural system can significantly integrate the stability and economy of sports architecture.

Structural optimization design search for the most optimized methods in the feasible region, this design process while also gives great inspiration on the necessary and reasonable design program of the cooperation procedure between architects and structure engineers. In traditional architectural design process, the generally functions and modeling scheme firstly proposed by the architect, once the project has been recognized, the structural engineers carry out structural calculations of architecture design, and then tie in other professional job such as construction equipment to coordinate. However, in the large and complex sports architecture types, the kind of design method will often bring up contradictory between surprisingly form and solid structure, the structural components also conflict with various types of pipeline device. Thus, more advanced design method and software have begun to use to change these defect. Especially for structural calculations and selection, contemporary advanced design methods have been fully reflected in their visibility, coordination, simulation and other advantages which provide the most favorable tools of sports architectural optimized design.

For example, there have been many design organizations take the building information modeling (BIM) as an effective way of optimized design. The powerful BIM can clearly show the scale and position as well as the connection of the structural components, it simultaneously avoid collision problems between the different structures and equipment. (Figure 3) Moreover, the establishment of BIM will involve the entire design, construction, operation process, in fact it establish an advanced design platform which can self-regulate and optimize constantly. The deep optimized design mainly affected by the information and complexity of building, exactly the model of BIM can provides a large amount of the actual existence of buildings, including geometry information, physical information, rule information, and even include the information of the rebuilt, removal of decomposition^[5,6]. While the complexity of large sports buildings beyond the capacity personnel limit involved in the work, it strongly requires an integrated design system coordinates all kinds of information. Therefore, BIM and its supporting optimization tools provide fully optimized possibility of the project and construction of sports complex.

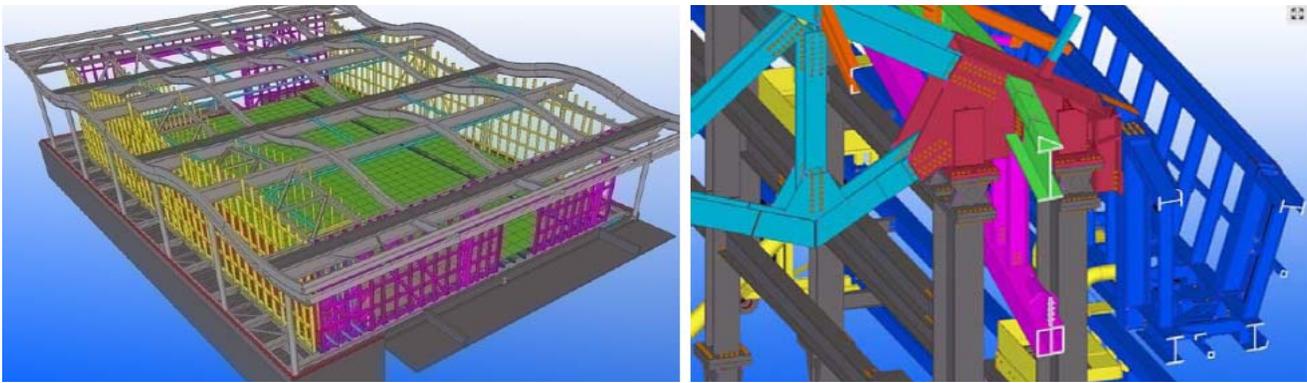


Figure 3 : BIM can provide comprehensive and detailed three-dimensional virtual model of the building

One excellent instance of the use of BIM technology is ASB Sports Centre at Wellington, New Zealand. The owners and investors hope the sports center contains twelve standard basketball courts under a large span roof which provide sports places for local residents and students. Because of the economic factors, it required to avoid excessive cost and material consumption. Designers established the BIM model by Revit software, make the structure more solid and economic after accurately calculated and compared by optimized design: the nearly oval roof is divided into two parts, designer use eight large fish-belly truss as the main support system at each side. The overall structure is just similar to the animal spine rather than the pursuit of super-span, and the spacing of truss part exactly leaving a suitable location for the roof skylight. Designers also use the Y-shape steel columns and steel cables to support and stabilize the structure system. Compared with the grid structure, the simple structure combination with steel truss and vertical support saving a lot of structure materials, furthermore it simplifies the pre-stressed technology of hybrid structures such as beam string needed to impose. Therefore, through the establishment of BIM, the architectural shape, the construction units, the structure node have been successfully achieved. Ultimately the method of optimized design mold the concise and practical architectural form by lower costs and material consumption, and to improve the function located in the beautiful scenery. (Figure 4)

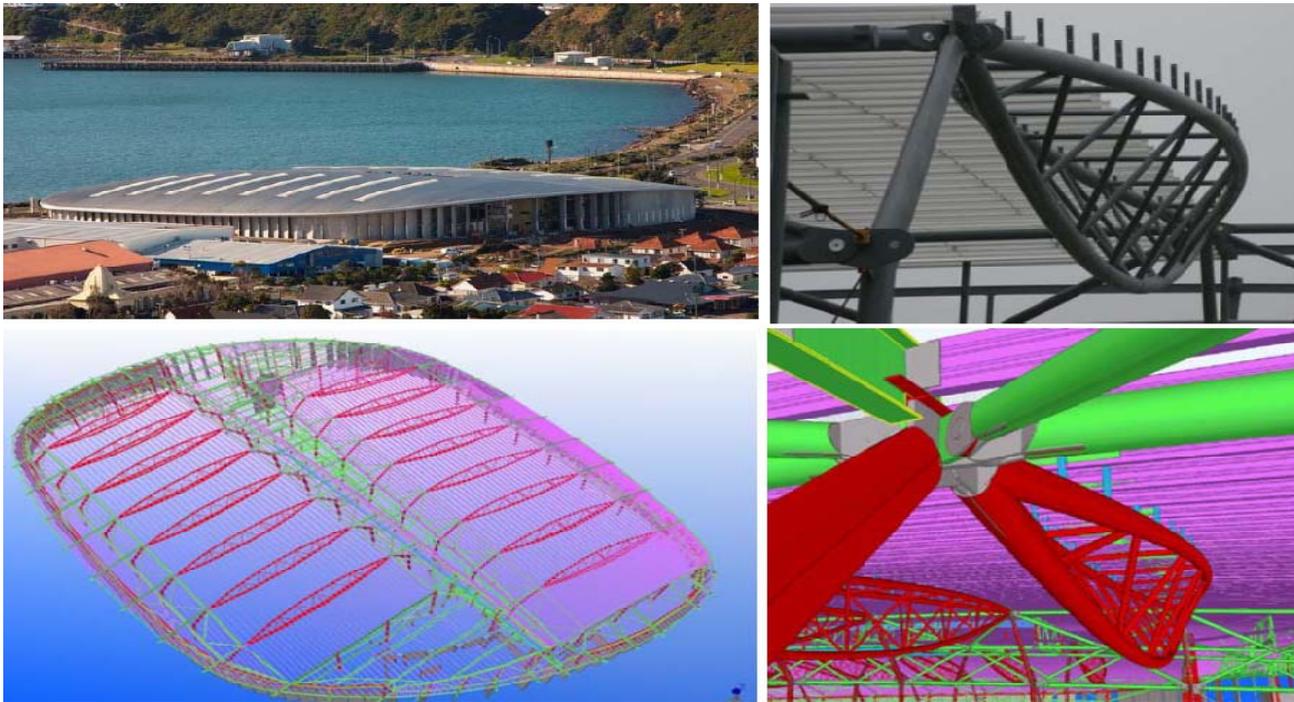


Figure 4 : BIM can provide comprehensive and detailed three-dimensional virtual model of the building
The materials saving of architectural surface

Obviously, the optimization of the structure efforts to maximum the performance of structural materials based on ensuring the structure safety. From the perspective of the development trend of sports architecture, people began to reflect on these serious problems space such as mismatch and materials waste caused by the blind pursuit of the large-span, thereby hope the "skeleton " and " skin" of sports architecture have reached the optimum state and its space is suitable and sustainable. Therefore, the optimization of structural system is bound to make full use of architecture space, and to promote the form more compact, the morphological characteristics and epidermis form of sports architecture determines whether or not to save their envelope material. Accordingly, the envelope systems dependent on the optimized structure can also carry more performance meaning combined with local materials, and it will not be look roughness and crude due to material savings. What is more, the optimized design of the envelope system not only reduce the weight of the roof and facade, reducing construction costs and energy consumption, but also give full play to the physical properties of new materials, it is fully in line with the life-cycle sustainable concept of sports architecture^[7].

Relative to the structural stability, the optimization of envelope means "suitability". As the successful examples in using of BIM to create a refined and efficient structural system, the ABS Sports Center also use optimized design of the exterior envelope system combined with the objective environment including local climate and materials. In the light of New Zealand's maritime temperate climate and abundant sunshine, but the larger temperature difference between day and night. Therefore, the designers use simple and appropriate envelope material on its roof and walls: A large number of translucent panels are installed on its roof to introduce natural light and filter ultraviolet. In large area of the facade with a good thermal insulation capacity of concrete materials which is easy to construction and low cost, and people arrangement these precast concrete panels to create the huge scale blinds according to the angle of the sun staggered. Apparently, these simple materials were able to meet the natural lighting and ventilation requirements of the sports center, in full compliance with the essential connotation of optimized design. (Figure 5)



Figure 5 : ABS sports center use simple and appropriate envelope material according to the local climate characteristics

With the enhancement of the aesthetic requirements, the external envelope of many sports venues also evolved into “Architecture Surface” to show more materials vocabulary. In response to this trend, the optimized design is mainly reflects to the elaborate building curtain wall. The powerful capabilities of BIM and other optimized methods can be more in accordance with the details design of curtain wall unit, and more comprehensive control of the material properties of metallic, glass, wood or plastic, etc. The optimized design impelled these materials become reasonably and accurate surface units through powerful calculation and analysis. For instance, in the following gymnasium design, the architect taken advantage of BIM to simulate observed on the curtain wall systems which integrating facade with roof. Thus the whole surface is constantly adjusted by the parameters of variables such as light radiation, sunshade, airflow, color etc^[8]. Ultimately the final solution of surface design is the most simple and reasonable, through objective and rigorous judge, these different materials were rational quantified and shaped. The designer optimized a large number of curtain units as several specifications of the panel fixed. Ultimately it really saved the project cost and improved the construction efficiency, and the complex surface of sports architecture is also solved perfectly due to the optimized design. (Figure 6)

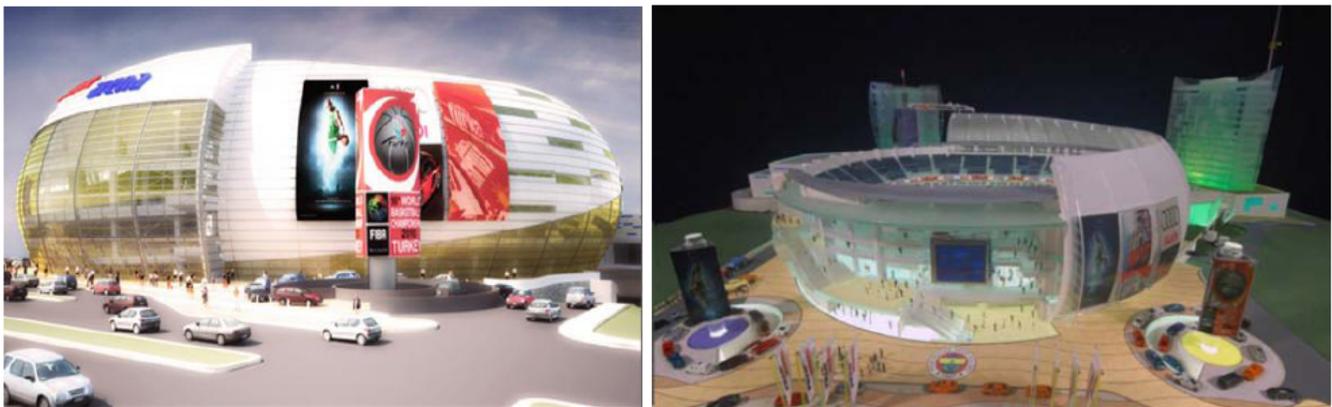


Figure 6 : The optimized panel of surface save the cost and improve the efficiency of construction

THE OPTIMIZED DESIGN COMPARED WITH PREVIOUS WORK

Undoubtedly, compared with the traditional design process, this kind of new design method can fully make use of the strong function of the software to create a complete control system, it not only be able to analysis the sports architecture with the complete section view, also can integrate the structure, surface and equipment system which be divided previously. The integration and optimization must be saving and efficient in the material form, and make sports buildings abandoned the overload and become more reasonable.

Furthermore, the tools of optimized design and the purpose of materials savings will be fully integrated by BIM and other advanced design methods. The designers can carry out the holistic optimized design with the idea of sound life-cycle depend on the various types and multiple functions of sports architecture. The measure would also make materials used more systematic and standardized to meet the complex requirements. Thus, the optimized design and the purpose of materials savings are complementary each other, the optimized design will no doubt give full play to the materials used combined rational logic with emotional creativity.

CONCLUSION

Sports buildings can fully reflect the material characteristics of the large span structures and the envelope surface, however many sports architecture design in order to meet the dazzling appearance requirements, stiffly and turgidly put the huge construction component or decorative skin covering the rational structure system, and the unreal shape also leads to structural imbalances. It is not only waste space and excessive consume materials but also demean the value of sports architecture which should provide the appropriate sports place for public. As for these huge sports architecture, if designer are able to take the most effective use of the materials and resources during the design process, it will certainly be more effective than any other saving measures in the life cycle of the sports buildings. Therefore, the optimized design can provide the correct direction and method to avoid material waste due to the exaggerated shape and irrational structure, and create the stable "skeleton" and pleasing "skin" for sports architecture by the refining and appropriate materials used.

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REFERENCES

- [1] M.Caroline, Clevenger, Ricardo Khan; "Impact of BIM-enabled design-to-fabrication on building delivery ", Practice Periodical on Structural Design and Construction, **19(1)** 122-128, (2014).
- [2] GaoYan;"Parametric design, A more efficient design technology and technique", World Architecture, **5**, 28-33, (2008).
- [3] Xu Weiguo, "Fold theory, Nomadic space, Interview on parametric architectural design", World Architecture, **8**,16-17 (2009).
- [4] Wu Yong; "Analysis of building structure optimal design", Science and Technology of Overseas Building Materials, **3**, 81-83 (2013).
- [5] O.Nawari, Nawari; "BIM-Model checking in building design", Structures Congress, 941-952 (2012).
- [6] O.Nawari, Nawari, Marcello Sgambelluri; "The role of national BIM standard in structural design", Structures Congress, 1660-1671 (2010).
- [7] Tang Shuonin, Yu Ruqing; "Design research on the skin of sports architecture from the perspective of new media Art ", Time+Architecture, **2**,111-113 (2013).
- [8] Li Huili, Zhang Shuosong, Zhang Xianfeng, "Parametric and collaborative design of sports building in the impact of digital technology", Urbanism and Architecture, **12**, 40-43 (2012).