

# Quality and Evaluation of architectural Structure Design -- Taking Several Structural Design Consulting as Examples

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**Abstract.** The construction project's feature is first settled by the design's quality. So as to to live up to the purpose quality's prime prerequisites, a written document review system for the intent drawings' design has been built in China to ensure that the design meets the intention standards' prerequisites for the project's construction, and the design written documents satisfy the intent depth's prerequisites. But in a quantity of respects, such as resource saving, surroundings cordial, constitution or modern technology covering ability, durability, performance, construction efficiency, disaster prevention and calamity rebate, it is required to take fraught consideration of stakeholders' views, throw back government management guarantee's prime prerequisites, and encourage the company to amend the requirements' quality management consciousness. From the standpoint of the development enterprise and the detailed technical work content of the architectural structure intention, assessment index's organization is an good direction to mobilize the initiative and gusto of the technical staff to meet the efficiency demands and efficiency of the evolution firm. By using several instances of reference and morphological design optimization, the main problems in morphological design's every respect are embodied. Though the prevailing intent package has put a lot of drawing work and scientific computing back, the advanced nature and innovation of the intention work yet needs to depend on the designer to fill it in. To comprehend the distinct qualities of connection and each design and have enough space for corresponding management measures is an effective way to improve constitution design's standard and scientifically assess the design's property.

**Keywords:** building structure design; design quality; design evaluation; design optimization

## 1. Introduction

Engineering rank is of terrific magnitude to the construction industry and yet the national economic development[1]. Improving construction projects' quality has been construction industry management's primary problem in China. So as to to consolidate the awareness of employees' quality management, the 'Interim Measures for the Investigation of Lifelong Quality blame of plan Authorities of Five Party Trustworthy Topics of Construction Engineering' (No. 124 of Construction rank) was followed through. The "Construction Law" and "Regulations on the Quality Management of Construction Plans" promulgated at the side of China have put forward clear requirements for construction projects' feature, determining that construction departments, survey units, design units, engineering superintendence items and construction flats are blamed for construction projects' property as reported by law. The state encourages the point of innovative science and technology and management ways to amend construction projects' rank.

Construction projects' feature is for the first time found out by the intention rank. The aim work is made up of a great influence on the quality control of the cost, duration management and total plan, so it is of neat signification to do scheme objectives' suave realization a respectable occupation of intent. Under the background of quality improvement, efficiency improvement and innovative development, design quality's improvement is particularly prominent. The degree and standard of engineering intention are also directly related to the safety of people 's lives and building and the character, role and profit of engineering. So as to to insure the elementary purpose standard and fit the safety of community and people 's lives and real estate, the United States, Britain, Singapore, Hong Kong and other economic developed rural areas and zones have

construction dragging review system[2].China 's' regulations on Construction Engineering's Administration Survey and Design 'put onward demands for survey's quality blame and design items, and'Regulations on the Depth of Compilation of Construction Engineering Design Written Documents' understandably defined demands for the intention depth that ought to be satisfied by aim written documents. Based on 'Regulations on Required Standards' superintendence for Construction Engineering'and'Regulations on the Required Provisions of Construction Engineering Qualities', a review system for construction that drew design written documents was set up to ensure that the design meets compulsory standards' prerequisites for construction engineering and the design documents meet the requirements of purpose depth that is stipulated at the side of the State. Now, the novel rooms, raw challenges and new typical, new situation of economic development is being faced by design units. Architects and purpose businesses need to prove the engineering intention concept of resource that saves, surroundings genial, good, creditworthy and advanced technology[3].High-performance structure's concept is likewise nominated in the domain of building constitution, reflecting higher structural bearing capacity, durability, performance, construction efficiency, and calamity prevention and mitigation capacity[4]. Based on the drawing review system's basic requirements, how to promote design quality's improvement and meet the needs of society's higher quality development therefore is a more urgent trouble.

From a technical standpoint, construction projects' quality refers to the elemental requirements more often than not for the safety, applicability, durability, ease, economy, environmental support and esthetics of plans under the regulations, technical qualities and prevailing laws. The more gamey prerequisites for the feature of construction schemes or the more gamey requirements for a certain performance index like safety, applicability, durability, consolation, economy, environmental protection and aesthetics of the project need to be mirrored in written documents and contracts like design and construction, from which the construction quality and intention quality in construction projects' quality can be improved. This idea of separating higher technical requirements and the basic technical requirements of construction quality is reflected in specification revision's new round.Such as' unified standard for acceptance of construction engineering construction quality 'GB50300-2013 and' construction engineering construction quality evaluation standard 'GB / T50375-2006 acceptance and evaluation of separation and different levels of requirements. Qualification is required, good is advocated, reflecting government management assurance's elementary prerequisites, and encouraging association to sharpen the quality management consciousness.In order to ensure that aim quality's elemental demands are fulfilled, the intention written documents must be compiled as stated by the project approval papers, the compulsory standards of engineering construction and the depth prerequisites of engineering design in the 'Regulations on the Management of Construction Engineering Investigation and intent'. For design quality's higher requirements, in the past, 'Quality Assessment and Quality Characteristics are Documented by Engineering intent -- Guide' (Construction 111) and 'Civil Building Engineering Design Quality Assessment Standard' were issued by China Architectural Design Association in 1992. This assessment standard is mainly used by the competent government departments for the evaluation of civil building that engineers aim quality in national design units and for the evaluation and self-examination of intent unit is designed by feature within each[5].

From sociable growth requirements' point of view, people 's necessities for a more respectable life, more high-pitched efficiency and efficiency of evolution investment, there is still a lack of an applicable quality for more high-pitched prerequisites for purpose feature. The conceptual design, optimization aim and okay purpose underscored technically are all measures from design's point of view. How to lift the new quality connotation that be based on the long-established engineering quality concept needs to be reflected in the evaluation and purpose property prerequisites[1].

## 2. Requirements for Structural Design Quality

The primary technical prerequisites for the standard of building structure intention in China 's'

construction that engineers quality management regulations 'and' construction engineering survey and aim management regulations 'can be summarized as running into engineering construction's required standards and the design depth of intent written documents similar to national regulations. Structural design quality's higher requirements are mainly reflected in structural design quality's evaluation in the 'Civil Building Engineering Design Quality Evaluation Standard' compiled by China Architectural Design Association in 1992, which is mainly thrown back in five aspects:

- To follow the policy and national construction policy, and the current regulations, qualities and procedures through at all points can run across the requirements;
- the structural scheme, system layout, structure, economic and technical indicators are sensible, appropriate and convenient for construction;
- The design precept information, outcomes and basis are correct, reasonable, clear and complete, which are consistent with the drawings;
- The drawing design depth, standard, graphic quality and experienced signing can all meet the depth and standard, and the expression is correct, and the design drawing is clear without error;
- structural scheme design has innovation, the application of new technology, new structure, new theory, new materials, etc., advanced computing software's use, comprehensive benefits with the domestic paid near design's floor in advance.

It throws back the intent departments 'appraisal and government of design quality mainly in five aspects: compliance, reasonable scheme, application, gratification and technological breakthrough or innovation. Now, Zhejiang Province has issued the "Implementation Point Of Views on Implementing the Primary Responsibility of Engineering Construction Units' Quality", which stipulates that the design standard ought to be effectively guaranteed. The original information that are provided by construction units that are germane to construction projects must be true, precise and total. Design units should not be required to design according to the reinforcement ratio of reinforced concrete engineering reducing the upper limit and the engineering quality standards of reinforcement amount per department that builds patch. Intention units should not be forced to boil down the safety of engineering constitutions and the employment of functional qualities. A third party department may not be commissioned to reduce the quality in the name of 'optimal design' by changing the contents that are named by the original design functions for flat that relates to significant point and structural safety[6].

From the point of view of architectural structure's skillful purpose scale, the scrutiny of structural technology in the National Excellent Architectural Structure Design Award is mainly reflected in five aspects: innovation and development in architectural structure's design, solving hard structural issues in the design of architectural structure, adjusting to architectural function's requirements in architectural structure's design, being made up of a significant role in improving the quality and speed of construction, and achieving singular economic advantages. Evaluation relies on technical and professional personnel mainly, reflecting the development and progress of the industry. Starting from setting environment-friendly green building and a resource-saving up, this paper creates an evaluation system of light-green residential building formation design that is based on grey clustering way in five aspects: stretching building out saving country, outside surroundings, vigor utilization and energy saving, and life water saving and water resources utilization and material and corporeal resources utilization, to measure the immature grade of making formation purpose, and show the more eminent prerequisites of environmental performance indicators and resource[7]. From the point of view of structural system's carbon issues, interbred structural system though tube-in-tube concrete structural system's economy is more wonderful than that of steel pillar frame-concrete core duct[8], its carbon issues are greater than those of steel column frame-concrete core tube hybrid structural system. of course, there are also various types of development enterprises or party A to develop design delivery standards, reflecting different development enterprises' requirements in engineering practice for their own productions, such as more detailed and specific requirements in component design, morphological choice, economic or corporeal indicators and reinforcement formation.

In terms of the demands for architectural structure design's quality, different stakeholders therefore have different requirements for concern's different contents. Similar to the requirements of the multinational construction industry for the design standard, its significant feature is to look at stakeholders' opinions to the full. Having enough space for stakeholders or civil institutions as the core instead of the professionals and original government as the core process is particularly obvious in determining architectural design quality's evaluation subject. The quality requirements of making structure design can be resource-saving, environmentally affable, secure and responsible, advanced to technology, sensible economy, convenient construction, novel and unique. It can in a similar way be high bearing capacity, good durability, unusual performance, mellow construction efficiency, solid calamity prevention and mitigation size. From development enterprises' perspective, combined with architectural structure design's specific technical work content, it is an effective way to understand and improve architectural structure design's quality so as to establish evaluation indexes to mobilize the initiative and enthusiasm of design technicians to meet the efficiency and be beneficial to development enterprises' requirements. With the introduction of information technology like BIM technology, big data and artificial intelligence into structural design and architecture, the '14 th Five-Year program' puts industrial digital transformation's promotion forwards distinctly. It is the same a lineaments of current development from unilateral emphasis on designers to emphasis on technical means. For example's program, in light of the issues that exist in the application and popularization of BIM in China 's that engineers construction informatization, the D-PDCA double cycle model is propounded. Consolidated with the management function theory, the 'data-center-decision' (DCD) engineering construction informatization management style is suggested, which provides the application of engineering project informatization, the digital transformation of firms and the construction of urban information model referee[9]. The design industry's digital transformation therefore is a more effective and scientific notion to meliorate the design quality.

### **3. Several Structural Design Consulting Examples**

#### **3.1 Design Optimization of a Super High-Rise Building Structure**

A hostel tower is a 180-meter high-rise that builds with structural transformation and frame-core duct formation at the 34th floor[10]. In the structural intention optimization, the most important structural system, floor formation, load audit and construction getting reinforcement audit are principally optimized. The chief structural system's optimization compares the steel that is added to principally concrete pillar frame core pipe, reinforced concrete frame core tube and concrete filled steel tube column frame core tube system, and optimizes the steel bone size in the steel that is strengthened concrete column, the adjustment and optimization of the non-transfer pillar and transfer column, the adjustment and optimization of the steel reinforced concrete column from the bottom to the floor, and the optimization and adjustment of the shear wall formation holes. The inclined smile is cancelled in the optimization of floor structure, which can keep away from unorthodox floor slab's generation. Secondary beam's layout is converted into two-way secondary balance beam layout. The segment zone of secondary balance beam and main beam is reduced, the reinforcement amount is brought down, and floor slab's thickness is appropriately boiled down. Load audit is to confirm the adjustment size and load calculation mainly. In construction drawings' reinforcement audit, the non-strengthened layer's reinforcement is estimated by the plastic theory plate, and the reinforcement is carried out following the estimated value, and the reinforcement is appropriately strengthened at the feeble position. Apart from the coupling beam and frame beam, the beam reinforcement does not have long negative moment reinforcement. Under the specification's requirements, the reinforcement ratio is controlled in the reasonable range of 1.0 % ~ 1.5 %. The column's axial compression ratio is controlled to ensure a sensible degree of enrichment, so as to realize the feeble beam and stiff pillar. Below the premise of meeting the specification prerequisites, the construction drawing's reinforcement consequences are every bit careful as

possible to the reckoned value. The straight distribution reinforcement and horizontal distribution reinforcement of by and large shear wall use structural reinforcement to meet the specification prerequisites, so that the final results are as close as possible to the estimated value. Through the above adjustment, it can be seen that the amount of reinforcement and concrete intake of beams, columns and shear walls have decreased, and reinforcement's fall and concrete intake of balance beams, pillars and shear walls is the most clear. by about 5.5 %, the beam reinforcement decreased; concrete consumption that is decreased by about 11.6 %; by about 5.6 %, column reinforcement reduced; by about 7.8%, concrete decreased; shear wall reinforcement that is reduced about 9.3 %; concrete consumption that is decreased by about 11.5 per cent. See below Table 1 for details.

Table 1. Reinforcement and concrete reduction of beams, columns and walls

Component name	Beam reinforcement quantity	Volume of beam concrete	Column reinforcement quantity	Volume of concrete column	Shear wall reinforcement	Concrete quantity of shear wall
Reduction (%)	5.5%	11.6%	5.6%	7.8%	9.3%	11.5%

In this plan case, beam was inclined by the component layout, reinforcement, and main structure system and secondary beam layout in component calculation, reinforcement and floor structure are adjusted and optimized, so that the quantity and the structural layout of building materials are more reasonable, which belongs to the suitable and sensible design quality requirements of structural scheme, system layout, structure, economic and technical indicators. It not only keeps away from corporeal waste, but also is aware of the goal of low carbon and environmental safeguard. In particular, under the premise of meeting architectural design's needs, good structural scheme will reduce the amount of material greatly[11].

### 3.2 Structural Design Consultation of a Logistics Warehouse Project

An importance food that trades distribution center project is located in Haicang Free Trade Zone of Xiamen City. The total building area is 59763.8 m<sup>2</sup>, of which 2 # buildings and 1 # are 8-story warehouses and the construction height is 47.15 m. By fixing seismic joints, it is partitioned into three monomers. 3 #, 4 # for 7-storey warehouse, setting height 41.15 m up. The ground floor is a garage, unmanned, warehouse floor height of 6 meters[12].

Each monomer in the original program is concrete frame-shear wall constitution. Following the general situation of the 7 degree and this construction project Xiamen area's seismic requirements, for this type of formation near to 50 m, if the frame structure is directly used, the lateral displacement opposition is not enough, and the more secular displacement point of view is not loose to meet. Concrete materials' big use will be caused, as long as the concrete frame-shear wall structure is selected. The steel support-concrete frame structure provided in Appendix G.1.3 of 'code for buildings' seismic design' GB 50011-2010 is used to replace the shear wall in the original scheme with steel support, so as to play steel support's role in resisting lateral force. Necessities 5851.14 m<sup>3</sup> concrete and 106.1 tons of reinforcement are walled by the design calculation shows the original shear, and 543.1 tons of position steel are needed by the steel cover. It can be found that the quantity of corporeal concrete run for replacing shear wall with steel cover is reduced. At the same time, in comparison with the concrete frame-shear wall structure and the steel support-concrete structure, the corresponding seismic force is reduced by about 40% due to the fall of the structure.

In summary's overall stiffness, steel-supported concrete frame structure's computation index is more reasonable, and the environmental advantages and resource are safer beneath the shapes of dependability and safety. The establishment scheme's beam-slab constitution is replaced by the

scheme of adding 0.3 m thick watertight plate without foundation beam. In comparison with the original scheme, after having enough space for the foundation beam, a total of 206 cubic meters of concrete is saved, the amount of earthwork excavation is depleted by 206 cubic meters, before 206 cubic meters, the foundation beam's reinforcement is kept by 201.8 tons, and the amount of the establishment beam's brick masonry is delivered by 586.6 cubic meters. The economic benefits that are generated by the construction period's saving, and the convenience of management that is caused by the manual reduction are not included by this cost.

### 3.3 Structural Design Optimization of a Seascape Hotel

A ocean opinion hotel's absolute house domain is about 915 thousand square meters. The luxury five-star hotel, which integrates the catering, whole sea view accommodation, leisure vacation and entertainment, has both duty and vacation operates. The layers and zone of each building are shown in table 2 less than. The upper constitution is skeleton structure, site group III, characteristic period 0.65s, building fortification intensity 7 degrees, the adapted necessary wind burden  $0.8 \text{ kN/m}^2$ .

Table 2. Building Gross leasable area and floor numbers

architecture name	situation of building	Building height (m)	Area (square meters )	Compensated buildingarea(sqm)	Inadmissible floor area ( underground ) ( square metres )
Welcome building	5F/1F	23.9	8050.79	24506.08	6603.12
Room1 #	7F/1F	30	2269.85	13398.93	
Room 2 #	7F/1F	30	2269.85	13400.68	
1# apartment hotel	7F/1F	23.9	1936.06	12025.78	6324.5
2# apartment hotel	7F/1F	23.9	1727.26	11287.73	
3#apartment hotel	2F/1F	8.4	422	1059.58	
5#apartment hotel	2F/1F	8.4	422	1059.58	
6#apartmenthotel	2F/1F	8.7	443	939.77	
total			17540.81	77678.13	12927.62

The optimization work is carried out mainly:

- The setting the model's parameters and the arrangement of the load between beams are modified. For instance, the beam is calculated according to the T-section, and the rigid region's role is considered in the column and beam. The corresponding live load discount should be considered in the purpose of establishments and fields.

- The following treatment methods should be considered for the partition wall's load on the slab: 1) when calculating the floor slab's reinforcement, it should be treated according to Appendix C of 'Building 50009 for Structural Load Code' GB -- 2012; 2) in the whole calculation, as stated by the brick wall's de facto burden input, it is unnecessary to input the transformed load, which can reduce the structure's weight effectively.

- The floor thickness is reasonably adopted as stated by the factual load, the reinforcement value and the floor span.

- According to reinforcement calculation's compliance and the rationality of reinforcement configuration, the corresponding reinforcement and size optimization of pillars, floors and balance beams are carried out. For instance, floors' minimum reinforcement proportion is reduced, and the reinforcement amount of structural plates

- of guest buildings, apartment hostels and visitor constructions can be optimized in big areas.

- The reinforcement the beam's configuration should be based on the model's determination outcomes, and the reinforcement value ought not to be enlarged. The smile longitudinal reinforcement should minimize the number of steel bars, so as to lift the section's effective height, the force is more sensible, and the quantity of longitudinal reinforcement can be optimized.

- The the column's reinforcement, in principle to meet the calculation requirements, and morphological prerequisites can be no longer broadened reinforcement.

Statistical computation of each that built in the floor steel optimization were 31.4 tons, 79.4 tons, 28.8 tons, saving 139.6 tons of steel. It can be seen that structural parameters' correctness, the precision of burden, the conformity of determination model, the rationality of calculation method, the conformity of reinforcement computation, the rationality of reinforcement configuration and economy have brilliant impact on morphologic design.

### 3.4 Quality Evaluation of Building Structure Design

It can be found from these structural intent consultation instances that due to the drawing review's foundation system and the delivery requirements of design results in China, the basic requirements to encounter the design quality are guaranteed. But the design belongs to the human intelligence activity, under the premise of meeting purpose quality's basic requirements, the accuracy, great difference will be caused by conformity or accuracy of various kinds of factors in the design process in the overall design quality. In more excellent design's being away third-party audit, optimization and quality prerequisites is a market-oriented implementation method[13].

In the evaluation of architectural structure design's quality, on the one hand, it is to see whether the design work is in place. As reported by the elementary design precepts, each intent link is scientifically and accurately done. On the other hand, it is to see the design's purpose notion process, which reflects improvement or innovation in designers' overseer. Due to structural design software's development, architectural structure design's a lot of scientific calculations are completed by software. Designers are more faced with the macro grasp of the accuracy and the overall structure scheme, accuracy or compliance selection of each design link.

From the whole structural design process' point of view, in line with the current norms' requirements, regulations and standards can rely on drawing software implementation and review, but the literacy and design thinking of structural designers can be best reflected by the system layout and structural scheme to solve engineering problems, and the link that can best reflect the level and design quality is difficult to be realized by drawing software and review. People desire to sort out structural scheme design's problem by means of artificial intelligence, expert system, database, composition mechanism and other scientific means [14-15].It, however, is not still able to replace structural designers. Structural design's innovation and the application of new structures, new technologies, new materials and new theories still need to play designers' subjective initiative. The structural design calculation after the system layout and structural scheme are determined mainly includes load calculation, calculation and calculation diagram model, deformation calculation and structural internal force, component design, construction and reinforcement calculation, etc., which is software's most important work instead of designers. The quality is thrown back in scientific precision, conformity or accuracy. The choice of data input, parameters and ways of designers has great impact on the results. In software's case is not automatically designed to complete, the understanding and designer 's knowledge level is particularly important. There is no ideal tool at present, although supporting tools have been developed to assist designers at home and abroad[16]. With reinforcement's determination consequences, structure and other construction drawing intent is the most difficult part of the application to solve, there is no uniform algorithm, alone specification supplies are representative characteristics. It relies on the provisions' designers 'understanding and consideration of construction convenience mainly.

Therefore, although there is a high understanding of intent quality's usefulness, it is stock-still difficult to set a accurate and scientific evaluation system up. Although there are some attempts[17], but motionless far from practical use, the necessity for joint endeavours to explore and achieve.

## 4. Suggestions

The scientific appraisal and advance of architectural structure design quality is an urgent issue to

be examined. The innovation of layout and structural system is involved by the structural design, whether it is suitable for buildings, whether the components are reasonable, whether the model, method and burden value are accurate and realistic in the calculation of effect and structural effect, whether structural components' construction is practicable and convenient, and whether the performance the final's indexes structure satisfy safety's prerequisites, applicability, comfort, durability, sustainability, economy and innovative. From the three gotten through structural design consultation examples, it can be seen that it is a feasible way to achieve higher grade and feature by using optimization mechanism or audit.

In the case of establishing the basic quality assurance system of drawing review, how to encourage enterprises and society to pay attention to design quality's amelioration and stimulate the enthusiasm and initiative of designers to improve design quality is the key to establish a sound market environment. A lot of workloads of drawing and scientific calculation are replaced by the current design software, but the advancement and innovation of design work still need to rely on designers. Taking corresponding management measures and understanding each design link's dissimilar traits are effective solutions to this dilemma.

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