EVOLUTION OF THE SAUDI BUILDING CODE FOR CONCRETE STRUCTURES (SBC 304)

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ABSTRACT

Saudi Building Code for Concrete Structures (SBC 304) focuses on guidance and guidelines for proper and safe design and construction of concrete structures in Saudi Arabia. It is also regarded as the major guard against the large uncertainty in the determination of modes of failure of structural concrete when subjected to some specific loading and environmental conditions.

This paper will present the evolution of the first SBC 304. The first part of the paper will discuss the different parts of the code and highlight the different areas that covered by the code. The second part of the paper will focus on the steps needed to implement the concrete code. The last part of the paper will shed some lights on the advantages of enforcing SBC 304 on the quality of the local and imported materials related to buildings and the impact of that on the life cycle of our infrastructure.

KEYWORDS

Codes, Saudi Building Code, SBC 304, ACI 318.

INTRODUCTION

In the last four decades, Kingdom of Saudi Arabia has witnessed great deal of advancement in different fields. Of particular is the construction of modern, huge and challenging structures which were mainly made of reinforced concrete elements. Unfortunately, significant parts of the structures were built in the absence of stringent and unified local building code. Thus, a sizable part of our structures were constructed in the absence of minimum safety provision assurance, absence of qualified supervision, lack of unified reference for error free design, lack of qualified building inspectors and clear inspection process, different construction materials with vast range of engineering properties. Therefore, many of the existing structures are now suffering from different

types of deteriorations and may not be adequate for the actual service life and environmental conditions. Such a practice is currently causing a great burden on our national economy. The only practical way to push back such a problem is to stop its progress. Because of that the National Building Committee was formed to establish the complete Saudi Building Code (SBC). Now SBC in its 13 volumes is ready and will be implemented in the near future [1]. An overview of this code i.e. SBC 304, is presented in this paper.

MAIN PARTS AND CHAPTERS OF SBC 304

SBC 304 is composed of six main parts, twenty one chapters and seven appendices. They are listed next:

Main Parts

1. General
2. Standards for tests & materials
3. Construction requirements
4. General requirements
5. Structural systems or elements
6. Special considerations

Chapters

Chapter 1	General Requirements
Chapter 2	Definitions
Chapter 3	Materials
Chapter 4	Durability Requirements
Chapter 5	Concrete Quality, Mixing, And Placing
Chapter 6	Formwork, Embedded Pipes, And construction Joints
Chapter 7	Details of Reinforcement
Chapter 8	Analysis and Design-General Considerations
Chapter 9	Strength and Serviceability Requirements
Chapter 10	Flexure and Axial Loads
Chapter 11	Shear and Torsion
Chapter 12	Development and Splices of Reinforcement
Chapter 13	Two-Way Slab Systems
Chapter 14	Walls
Chapter 15	Footings
Chapter 16	Precast Concrete
Chapter 17	Composite Concrete Flexural Members
Chapter 18	Prestressed Concrete
Chapter 19	Shells and Folded Plate Members
Chapter 20	Strength Evaluation of Existing Structures
Chapter 21	Special Provisions for Seismic Design

Appendices

Appendix A	Strut-and-Tie Models

Appendix B	Alternative Provisions For Reinforced and Prestressed Concrete Flexural And Compression Members
Appendix C	Two-Way Slabs – Coefficients Methods
Appendix D	Anchoring to Concrete
Appendix E	Notation
Appendix F	Steel Reinforcement Information
Appendix G	Design Aids

BASE CODE FOR SBC 304

The base code for SBC 304 is ACI 318 2002 [2]. However, the base code received several types of modifications to reflect Different local and practice conditions within the Kingdom of Saudi Arabia (KSA). These include:

- Different soil conditions available within the KSA territories (Sabkha soil, expansive soil);
- Environmental conditions (hot-dry and hot humid conditions);
- Slab system (irregular slab system construction);
- Different yield stress of reinforcing steel;
- Loading at different stages of construction; and
- Local seismic and wind loadings.

A brief description of the major modifications made is presented in the following sections.

DURABILITY REQUIREMENTS

Durability issue is very much aggravated by the hot-dry, hot-humid and other severe environmental conditions prevailing in most parts of the Kingdom which are not covered adequately by the ACI 318 Code. Therefore this part received a major review and modifications. For comparison the durability section (Ch. 4 of SBC 304) is presented next before and after modification.

Before modifications the chapter is composed of

4.0 – Notation
4.1 – Water-cementitious material ratio
4.2 – Freezing and thawing exposures
4.3 – Sulfate exposures
4.4 – Corrosion protection of reinforcement

After modifications the durability chapter is composed of:

4.0 – Notation
4.1 – Water-cementitious material ratio *(Major change)*
4.2 – Freezing and thawing exposures *(Deleted)*

4.3 – Sulfate exposures *(Major change)*
4.4 – Corrosion protection of reinforcement *(Major change)*
4.5 - Sulfate plus chloride exposures *(New)*
4.6 – Sabkha exposures *(New)*
4.7 – Salt weathering *(New)*

Further details about the contents of these titles of the chapter are presented next:

Sec. 4.3 – Sulfate exposures (Major changes)
Requirements were simplified by removing materials not relevant to the Kingdom. Table 4.3.1 was simplified and requirements for the minimum cementitious material ratio were introduced.

Sec. 4.4 – Corrosion protection of reinforcement (Major changes)
4.4.1 - Limits on concentrations of chloride ions in hardened concrete (Minor)
4.4.2 - Chloride from external sources *(Major & New Table 4.4.2 specifying exposure conditions)*

New sections were added to explicitly specify the requirements for several common exposure conditions prevailing in Saudi Arabia as follows:

New subsection 4.4.3 - For the permanently submerged, tidal, splash and spray zones of marine structures, the requirements for very severe exposure in Table 4.4.2 shall be satisfied.

New subsection 4.4.4 - For concrete structures near to or on the coast and exposed to airborne salt but not in direct contact with seawater, the requirements for severe exposure in Table 4.4.2 shall be satisfied.

New subsection 4.4.5 - For structures in coastal areas and not directly exposed to airborne salt, the requirements for moderate exposure in Table 4.4.2 shall be satisfied.

New subsection 4.5 - Sulfate plus chloride exposures
If concrete is exposed to both chlorides and sulfates, the lowest applicable maximum water-cementitious materials ratio and highest minimum cementitious materials content of Tables 4.3.1 and 4.4.2 shall be selected. The corresponding highest f'c shall be the governing value for quality control purposes. The cement type shall be the one required by Table 4.4.2.

New subsection 4.6 – Sabkha exposures
Concrete structures exposed to sabkha shall meet the requirements for very severe exposure in Table 4.4.2, except that the water-cementitious materials ratio shall not be more than 0.35. In addition, the exposed surfaces shall be protected by appropriate means, such as tanking or epoxy-based coating.

New subsection R4.6 – Sabkha exposures
Gives detailed description of Sabkha, its main characteristics with respect to durability and known locations in the Kingdom.

New subsection 4.7 – Salt weathering
Concrete structures amenable to salt weathering shall be protected by applying an appropriate barrier coating.

New subsection R4.7 – Salt weathering
Concrete exposed to splash in a marine environment and soil with shallow groundwater table or water from irrigation is susceptible to deterioration due to salt weathering in the hot and arid environment of the Kingdom. In addition to utilizing quality concrete, it may be necessary to provide additional protective measures, such as the application of an appropriate barrier coating.
In marine structures, the protection should be provided in the splash zone. Tanking or application of a barrier coating in portions exposed to soil is necessary for the substructures.

HOT WEATHER CONCRETING

Hot weather concreting is an essential issue for concreting in Saudi Arabia and should be covered in details in The SBC-SC.

5.13 - Hot weather requirements in ACI 318
During hot weather, proper attention shall be given to ingredients, production methods, handling, placing, protection, and curing to prevent excessive concrete temperatures or water evaporation that could impair required strength or serviceability of the member or structure.

Hot weathering requirements in SBC 304
5.13.1 - During hot weather conditions, proper attention shall be given to ingredients, production methods, handling, placing, protection, and curing to prevent excessive concrete temperatures or water evaporation that could impair required strength or serviceability of the member or structure.

New subsection 5.13.2 **–** The temperature of fresh concrete shall be kept as low as practicable but shall not exceed 35 °C at the time of placing. Some of the measures that may be employed to control concrete temperature include: (i) shading aggregate stockpiles and bins, (ii) sprinkling water to cool coarse aggregates, (iii) cooling mixing water, (iv) using ice as part of mixing water, and (v) painting trucks, silos and other related equipments, with white or light color.

New subsection 5.13.3 **–** The use of chemical admixtures, such as retarders and water reducers, shall be considered to offset the negative effects of hot weather.

New subsection 5.13.4 **–** Steps must be taken to transport, place, consolidate, and finish the concrete at the fastest possible rate.

- Discharge of concrete shall be completed as soon as possible after the initial mixing at the batching plant. However, it shall not be more than two hours provided retarding admixtures are used.

- Concreting shall be done at the lowest ambient temperature, preferably early in the morning or late in the afternoon.
- Delivery of concrete to the job site should be scheduled so that it will be placed promptly on arrival.
- Unless otherwise required, concrete should be proportioned for a slump of not less than 75 mm at the time of placing to permit prompt placement and effective consolidation in the form.
- The construction activity should be carefully planned to avoid cold joints. If construction joints become necessary, they shall be made in accordance with Section 6.4 of this Code.

New subsection 5.13.5 **–** Retempering of concrete by the addition of water to compensate for loss of workability shall not be allowed.

New subsection 5.13.6 **–** All necessary precautions shall be taken to prevent plastic shrinkage cracking. In particular, precautions should be taken during placing of concrete to avoid excessive evaporation of mix water.

New subsection 5.13.7 **–** Curing of concrete shall commence as soon as the surfaces are finished and it shall continue for at least the first seven days. Moist curing for the entire curing period is preferred. However, if moist curing cannot be continued beyond 3 days, concrete should be protected from drying with curing paper, heat-reflecting plastic sheets, or membrane-forming curing compounds.

New subsection 5.13.8 **–** Tests on of fresh concrete and specimen preparation shall be strictly in accordance with the relevant ASTM standards by qualified technicians. Air temperature, concrete temperature, and general weather conditions at the time of concrete placement shall be recorded. Inspection of concrete shall be detailed and emphasized in project specifications to ascertain that adequate precautions are taken to minimize the adverse effects of hot weather on concrete properties.

TWO-WAY SLAB SYSTEM

New section about alternative method (other than direct design or equivalent frame design methods) for designing two-way solid slab should be added to chapter 19.

Seismic Provisions

- Section 1908 of International Building Code (IBC) -modification to ACI 318 - Seismic provisions and Section 1910 of IBC -Seismic design provisions- contain specific details about seismic design requirements which are not applicable in Saudi Arabia.

- The two sections need to be modified in accordance with the related modifications to be implemented on Chapter 16.

Minor Changes or Modifications

In addition to the major changes introduced into the ACI 318, tens of minor changes were implemented to make the SBC 304 more rational and applicable the Saudi Arabia environment and practice. These changes or modifications are related to the following issues:

- Cement Properties
- Mixing and Curing Water
- Testing Standard
- Quality Control
- Steel Bar Sizes and Grades
- Measurement Units
- Irrelevant provisions
- Terminology Modifications

COMPLIANCE WITH ISO19338

The SBC 304 is in full agreement with ISO19338 performance and assessment requirements for design standards on structural concrete. These include:

- General requirements
- Overall structural concept
- Structural integrity
- Overall structural concept
- Design approach
- Design service life
- Workshop, materials and quality assurance
- Performance requirements
- Structural safety and ultimate limit states
- Serviceability limit states
- Durability limit states
- Fire resistance limit states
- Fatigue limit states
- Loading and actions: general, load factors, action combinations, permanent loads, variable loads, accidental loads, construction loads, impact loads, earthquake loads, wind forces, and environmental actions
- Assessment which covers: Materials, analysis of concrete structures, strength calculations, partial safety factors for materials, resistance factors, resistance criteria, stability, precast concrete and composite action, prestressed concrete, design for earthquake resistance, detailing requirements, and fire and durability.
- Construction and quality control
- Construction requirements
- Quality control

STEPS NEEDED TO ENFORCE SBC 304

The purpose of the Code Enforcement is to promote, protect and improve the health, safety and welfare of the citizens of KSA by assuring the minimum safety provision to structures built in compliance with SBC code. Code Enforcement Division needs to be established to assure implementation of the code on any construction within the Kingdom of Saudi Arabia.

Appointing Enforcement Authority

Functions of Enforcement Authority are:

- To enforce the SBC 304 in the Kingdom
- Issuance of subpoenas;
- Taking of testimony;
- To issue orders having the force of law commanding whatever steps are necessary to achieve compliance of the violation of the code;
- To levy fines a first violation and repeated violations
- To lien property in cases where the violation is not corrected within the timeframe provided by the Authority order.

Inspectors

Construction and building inspectors examine the construction, alteration, or repair of buildings, highways and streets, sewer and water systems, dams, bridges, and other structures to ensure compliance with building codes and ordinances, zoning regulations, and contract specifications. Building codes and standards are the primary means by which building construction is regulated in the country to assure the health and safety of the general public. The structural design inspector will be:

- Reviewing the structural design documents associated with building permit applications.
- Verifying the compliance of construction documents with the SBC 304.
- Inspecting the work associated with building permits for compliance.
- Issuing Certificates of Occupancy when work is complete and in compliance.

Testing and certification programs

It is desirable to have testing and certification programs for the individual parties involved with the execution of work performed in accordance with the code.

BENEFITS OF IMPLEMENTING SBC 304

The benefit of implementing SBC 304 is to provide a high level of compliance for the preservation of life, safety and the general welfare for the people of KSA.

This is accomplished through the enactment and enforcement of SBC 304 and other parts of the code and standards to ensure the structural strength, sanitation, fire protection, adequate light and ventilation, and other essential elements of life safety in the built environment.

The code provides a means of establishing minimum standards for acceptance of designs and construction by a legally appointed building official or his designated representatives. The code is not intended for use in settling disputes between the owner, engineer, architect, contractor, or their agents, subcontractors, material suppliers, or testing agencies. Therefore, the code cannot define the contract responsibility of each of the parties in usual construction. General references requiring compliance with the code in the job specifications should be avoided since the contractor is rarely in a position to accept responsibility for design details or construction requirements that depend on a detailed knowledge of the design. Generally, the drawings, specifications and contract documents should contain all of the necessary requirements to ensure compliance with the code. In part, this can be accomplished by reference to specific code sections in the job specifications.

SUMMARY AND CONCLUSIONS

A brief description of the contents of the Saudi Building Code for concrete (SBC 304) is introduced. Some details about the steps to be taken to implement the code and the benefits of enforcing it have also been presented. Now it is the time to set well planned steps to gradually implement the code within a specified time schedule. It seems, however, many exhaustive works are required before the code be mandated.

REFERENCES

[1] Saudi Building Code, National Committee, Riyadh, Saudi Arabia.

[2] American Concrete Institute (ACI) Committee 318 (2002), “Building Code Requirements for Structural Concrete,” ACI 318-02, American Concrete Institute, Detroit.