STRUCTURAL DESIGN PRACTICE FOR RESIDENTIAL BUILDINGS IN RIYADH: AN OVERVIEW

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ABSTRACT

The design practice of structural engineers working in small design offices in Riyadh was examined. Design documents including design assumptions, calculation sheets and design drawings were collected for 41 residential building projects in Riyadh. Additional information were collected from the design engineer relating to his background, code of practice used (if any), and his general philosophy regarding analysis and design. In this paper, results relating to various aspects of the structural analysis, design, and presentation of the final design drawings are presented. In addition, discussion of the shortcomings of the current practice and ways to rectify them are also included.

Keywords: *Housing, Construction, Structural design, Design practice, Reinforced concrete, Saudi Arabia, Design code.*

الملخص

تمت دراسة ممارسات المهندسين الإنشائيين العاملين في تصميم المباني السكنية الصغيرة في مدينة الرياض وقد تم لهذا الغرض جمع وثائق التصميم وتشمل الفرضيات وكراسة الحسابات الإنشائية ولوحات التصميم لواحد وأربعين مشروعا لمباني سكنية في مدينة الرياض . كما تم جمع بيانات إضافية من المهندس الإنشائي المصمم تتعلق بخلفيته وكود البناء المسـ ـ ـتخدم (إن وجد) ونظرته بشكل عام إلي عملية التحليل والتصميم الإنشائي.

وتعرض هذه الورقة النتائج التي تم التوصل إليها في جوانب متعددة من الممارسات الحالية وخاصة منها تلك المتعلقة بالتحليل والتصميم الإنشائي وطريقة عرض لوحات التصميم النهائي. كما تم التطرق إلى العوائق و جوانب القصور في الممارسات الحالية وسبل تصحيحها.

1. INTRODUCTION

The design practice of housing is inflicted by many problems and shortcomings with the lack of local building code governing the design and construction being the foremost significant. Detailed account of the problems and shortcomings of the current design practice in Riyadh were given by Al-Jowair [1990]. These problems are believed to be common to other parts of the Kingdom. These problems are reflected in the unhappy relationship between owners and designers. In a recent investigation of the design of residential buildings in the eastern province of Saudi Arabia by Al-Hammad and Al-Hammad [1996], 20 interface problems between building owners and designers in the current practice were identified. These problems were classified into the following three categories: inadequate contract and specifications, financial problems, and lack of proper communication between the owners and designers. They found agreement between the owners and designers on the seriousness of these problems.

The structural design and systems used for housing have received some attention in the past few years. Al-Meddallah et al. [1991] argued against the use of reinforced concrete (RC) for residential construction as having many deficiencies and problems. They advocated the use of load bearing masonry instead of RC frames for low-rise residential buildings in the Kingdom. Advantages cited included significant cost saving and faster construction compared to RC frame construction. The need for a building code and the urgency has been recognized by many . Several research programs were funded by King Abdulaziz City for Science and Technology (KACST) with the objective of developing design code for RC structures [Arafah et al., 1989; Al-Haddad et al., 1991; Al-Zaid et al., 2000].

Construction problems of RC buildings in Riyadh were studied recently by Shuraim and Al-Negheimish [1995]. The study pointed to many site problems regarding RC construction and reinforcement detailing. One important finding from that study, was the high degree of adhering to the design drawings by owner and contractors. In general, it was found that the structural design drawings were closely followed on most construction sites. This means that improving the design practice will have immediate impact on the construction practice. On-going study supported by KACST is looking at rationalizing and improving the design of the RC frames with joist slab [Shuraim and Al-Negheimish 1998]. The structural system used for RC frame construction in Saudi Arabia has been criticized as needing rationalization [Al-Ghamdi, 1996].

Some of the problems of the structural design cited above are a byproduct of the lack of proper design methodology by structural engineers working in small design offices in Riyadh. Proper structural design process, in general, involves various steps of analysis and design. These consist of specifying material properties, selecting the appropriate geometric model including columns layout and slab system and the integrity of the structural system. Under the above mentioned conditions, the structure is normally analyzed under the applicable loading to obtain the internal forces and the resulting deflections. The next stage involves determining the final dimensions and reinforcement satisfying code requirements for strength and serviceability as well as durability for all elements of the structure. The final step in the design process is the presentation of the design using a format suitable for utilization by contractors. It is vital to find out how the above-mentioned process is carried out for the design of our buildings in order to assess adherence to proper practice.

2. STUDY METHODOLOGY

Data and design documents including architectural and structural design drawings, design assumptions and calculation sheets were collected for 41 residential building projects in Riyadh. Additional information relating to the design engineer background, code of practice used (if any), and the general philosophy regarding analysis and design were collected using simple questionnaire prepared for this purpose. In addition, copies of codes, handbooks and other data used by the designer were obtained for most projects. The data were collected with the cooperation of the Municipality of Riyadh and involves actual projects submitted to the Municipality approval. The selected projects are limited to villas, duplexes and low-rise apartment buildings and represent typical practice in Riyadh.

All the data and design documents collected were reviewed and studied for structural design assumptions and adequacy of the overall design features. In depth check of the structural design was performed on a selected number of cases covering typical layout and design. However, due to space limitation, the results of the in-depth check are not given here but can be found elsewhere [Al-Tayyar, 1998].

3. RESULTS

3.1 General Characteristics Of Buildings

3.1.1 Buildings types

Modern residential buildings in the Kingdom can be classified as either single-family housing (villas) or multi-family housings such as apartment buildings and duplexes. The villas are detached dwellings with a privacy fence on the property line constructed normally using masonry walls. Duplexes are semi-detached dwellings with more compact floor plan compared to villas. Most buildings are constructed using reinforced concrete framed structures with reinforced concrete flat roof deck slabs. Curtain walls and partitions are normally constructed using nonload bearing masonry walls.

According to this classification, 26 out of the 41 buildings in the study sample are villas, 9 are apartment buildings and 6 are duplexes or multiplexes. Two of the apartment buildings were designed for residential use only and the remaining 7 were for dual commercial and residential use.

3.1.2 Plot area and built-up area

Zoning regulations in Riyadh limit the percentage of built-up area to 60% of the plot area over most part of the city. The results of these zoning regulations were reflected in built-up areas for the three building types in the study sample. The percentages of built-up area in apartment buildings were the highest, with duplexes ranking second and villas third with mean values of 57%, 52%, and 40%, respectively. It was also clear from the data that the mean floor area is highest for villas with duplexes having the most compact floor area. These results were expected in view of the commercial aspects involved.

The plan layouts for most buildings were irregular. The irregularity included spans, loads, and dimensions of structural members (joists, beams, columns and footings). This complicates both the structural design and construction of the building.

3.1.3 Number of stories and story-height

Most of the buildings in Riyadh are two stories high due to zoning regulations. The construction permit for buildings with more than two stories is issued by the central permit office in the Municipality. In all the studied projects, the buildings were two-story high, with only 5 of them with basements. Some of the buildings had upstairs annex, which were about 10% of the first floor area. The heights of the ground and first floors were 3.0 m in all the projects except for the commercial apartment buildings where a height of 3.5 m was specified. The height of parapet wall was 1.8 m in all projects.

3.2 Designers and Design Drawings

3.2.1 Design engineers

The 41 projects in the study sample were designed by thirty-four consultant/engineering offices with some offices designing more than one project. Twenty-eight of these offices provided the name of the structural engineer and his nationality. Among those structural engineers named, 54% were Egyptians, 7% were Saudis and the rest were from other nationalities. These data clearly showed a strong Egyptian influence in the local structural design practice in Riyadh.

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3.2.2 Design drawings

In order for the municipality to issue a building permit, the owner of the building is required to submit design drawings for the Municipality approval. The drawings should come from an approved design office and cover the minimum architectural, structural, electrical and plumbing systems requirements. No formal written procedures or guidelines for the preparation of these drawings are given by the Municipality.

By and large, the drawings provided by the design offices meet these requirements. However, important issues such as presentation format and information to be included on the design drawings are not well defined and therefore left to the design engineer to decide upon. This was reflected in the different styles, formats and levels of details contained in the design drawings collected for this study.

3.3 Characteristics of Structural Members

Typically, residential buildings in Riyadh are built as reinforced concrete (RC) frames supported by isolated footings. All walls of the ground floor are supported by grade beams. The slab system is either solid slab supported on beams or joist slab with block filler known locally as "Hordi slab". In this section, data and information relating to the structural design of members such as types, frequencies, dimensions, thickness, and other aspects of the design are given.

3.3.1 Choice of slab systems

The slab system used is limited to Hordi slabs and solid slabs on beams. The percentage use of these two types is illustrated graphically in Figure 1. As can be seen from this figure, 37% of the projects used only Hordi slabs, 7% used solid slabs, and 56% used both in the same building. These data show the wide use of Hordi slabs as they were utilized fully or partially in 38 out of the 41projects or 93% of the total. The wide use of Hordi slab attributed to many factors the most important of which are:

1. They provide more flexibility for floor layout and future modifications
2. They are perceived to possess superior thermal and sound insulations
3. Ease of construction

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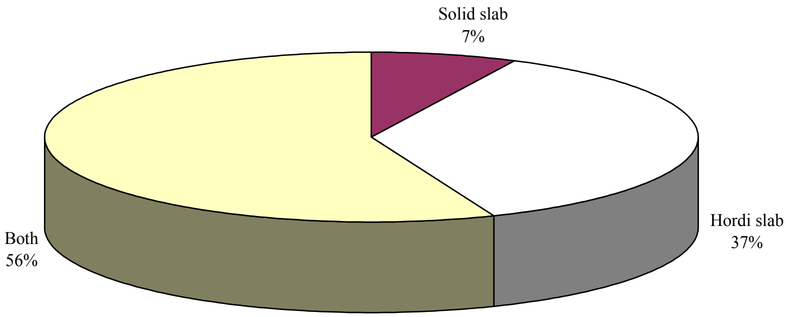

Figure 1: Type of slab system

Among the 38 projects using Hordi slabs, 39% used Hordi slabs in both floor and roof, 50% in first floor only, and 11% used Hordi slabs in selective areas only. It should be noted here that it is a common practice to use solid slabs in bathrooms even with Hordi slab construction. For Hordi slabs, the range of the slab thicknesses were 250-380 mm with the thickness 320 mm being the most common as it comprised 84% of the total. The 320 mm thickness for Hordi slabs is a result of using 250 x 400 x 200mm Hordi blocks and top slab of 70 mm thickness.

Among the 26 projects using solid slabs (fully or partially), 12% used solid slabs in both floors and roofs, 69% in roof only, and 19% used solid slabs in selective areas only. The range of the solid slab thickness used was 100-200 mm with the 120 mm and 150 mm thicknesses being the most common.

3.3.2 Beams

Typical types of beams used in buildings are grade beams , drop beams and Hordi beams (flat hidden beams). Widths of grade beams and drop beams depend on widths of the walls; however, the depths of these beams are variable. The range of depth used for grade beams was (300 mm - 800 mm) with common depth of 600 mm. For drop beams, the depths used were in the range of (400 mm - 800 mm) with 700 mm as a common depth. The number of groupings used for grade beams in each building was between 3 to 7, while it was 2 to 6 for drop beams. Hordi beam widths depend on design requirements, and Hordi beam depths depend on type of filler block used for Hordi slabs. The most common depth used for Hordi beam was 320 mm. The range of Hordi beam widths was (400 mm - 1600 mm), The number of groupings used for Hordi beams was between 2 to 4 .

3.3.3 Columns

Columns are critical elements in RC design. They carry loads from beams and transfer it to footings. The general characteristics of columns used in buildings in Riyadh can be inferred from the data collected. Due to the common practice of having the columns hidden in walls, the widths of most columns are the same as that of walls, while depths of columns depend on design requirements. The column depths were in the range of (400 mm - 1150 mm), with 600 mm being the common depth. The number of groupings used for columns in each building was between 4 to 7.

The total number of columns used for each building was (16 to 72) columns, with mean value equal to 35 columns. The range of area carried by each column was (7.8 m^2 to 26.3 m^2) with a mean value of 11.0 m^2. The number of interior columns used in each building was (2 to 40) columns, with a mean value of 14 columns. The range of floor area carried by interior columns was (10.7 m^2 to 40.5 m^2) per column with a mean value of 17.6 m^2. The number of exterior columns used in each building was (12 to 32), with a mean value of 21. The range of floor area carried by exterior columns was (4.2 m^2 to 18.0 m^2) with a mean value of 7.2 m^2. These data show the use of a large number of columns per building with each supporting only small area. Rationalization of design should reduce the number of columns and simplify the structural layout.

3.3.4 Footings

Footings transfer loads from columns into the ground below. The most common types of footings used in the foundations of residential building are the isolated footings. The minimum size of footings used is (1000 mm x 900 mm x 400 mm) while the maximum size is (2800 mm x 2800 mm x 600 mm). The number of groupings used for footings in each building ranges between 3 to 6.

3.4 Design Loads

3.4.1 Dead loads

Accurate estimate of dead load is an important factor in the structural safety and economy of the design. The assumptions regarding superimposed dead load and partition walls provided by design offices are evaluated as follows:

Superimposed dead load

Superimposed dead load resulting from the use of covering materials on the structural slab was studied based on assumptions documented in the design calculation. Data show that 80% of the engineers used a covering material weight of 1.5-2.0 kN/m^2 for first floor and roof slabs and 16% used 2.5 kN/m^2 or more for both floor and roof. Only four engineers used different weights of covering materials for first floor and roof.

By comparison, these values are believed to be underestimate for the actual superimposed dead load resulting from the use of covering materials applicable to the current construction. It is estimated that covering materials for first floor and roof are in the ranges of 2.0-2.5 kN/m^2 and 2.0-3.0 kN/m^2, receptively, depending on the construction practice and other circumstances.

Wall Weight

Usually, wall consists of blocks, mortar joints, and plaster of approximately 15 mm thickness on two faces. Wall weight depends on these components with the block weight being the most significant component. Block weight depends on many factors such as type of block, materials used, and size of block. There are two main types of block, concrete block, and red clay block. These blocks have different sizes like (200 mm x 200 mm x 400 mm), (150 mm x 200 mm x 400 mm), and (100 mm x 200 mm x 400 mm). An estimation for weight of the block was compiled based on data provided by other researchers [Al-Zaid et al., 2000; Amjad and AlSayed, 1995] for the common sizes used. The weight of red clay block is approximately 75 % of the concrete block. Also , data from AL-WATANIA BRICKS FACTORY showed that the weight of Hordi ceiling blocks (red clay) is equal 75 % of the weight of Hordi ceiling blocks (concrete block) for the common size used in construction of buildings which is (250 mm x 200 mm x 400 mm). So, by using red clay blocks for walls or Hordi slabs, a reduction of dead load for these members is possible. Typical wall widths used in buildings are 150 mm, 200 mm, and 300 mm composite wall. A double wall of 300 mm thickness may be used for exterior walls by using two sizes of block which are (150 mm x 200 mm x 400 mm) and (100 mm x 200 mm x 400 mm), and thermal insulation board 50-mm thick in between. Also, in some buildings, 200 mm or 150 mm wall width may be used for exterior walls, and some people used marble or stone as veneer for exterior walls. For interior walls, 150 mm thickness is typically used with 200 mm thickness being used in many cases.

The weight assigned for the 150 mm thick wall was in the range of 2.0 - 3.4 kN/m2, with a mean value of 3.0 kN/m2. For the 200 mm thick wall, the range was 2.3 - 5.0 kN/m2, and the mean was 3.5 kN/m2. For the 300 mm thick the range was 3.0 - 7.5 kN/m2, with mean of 5.0 kN/m2. The mean values for the wall weight are in reasonable agreement with our estimates [Tayyar, 1998].

The data of the study sample showed that only one structural engineer specified the type of block used in design. Unless the type of block is specified, the owner of the building and the contractor may use the much heavier concrete block. That means increasing dead load of wall and Hordi slab. Therefore, it is important, when the designer uses red clay block in his design, he should specify on the design drawings the type of block used. Another interesting observation was the limited use of double wall with thermal insulation where 14 projects (34%) used it. This means that the majority (66%) are using single wall 150 mm or 200 mm thick without provisions for proper thermal insulation.

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3.4.2 Live loads

According to ASCE 7-93, [ASCE 7, 1993] live loads in buildings are those loads produced by the use and occupancy of the building and do not include environmental loads such as wind loads, snow load, rain load, earthquake load, or dead load. Live loads on a roof are that produced (1) during maintenance by workers equipment, and materials and (2) during the life of the structure by movable objects such as planters and people. The loading given in building codes is intended to represent the maximum sum of these loads that will occur on a small area during the life of the building. The minimum uniformly distributed live loads for residential buildings are specified as [ASCE-7, 1993]:

Private rooms and corridors serving them, LL= 2.0 kN/m^2

Public rooms and corridors serving them, LL = 5.0 kN/m^2

For single family housing, the use of 2.0 kN/m^2 for first floor is reasonable since public rooms are normally located in the ground floor and the first floor is reserved for private rooms. Data showed that 75% of the Engineers used live load of 2.0 kN/m^2, 14% used 2.5 kN/m^2, 8% used 3.0 kN/m^2 and 3% used 1.5 kN/m^2. Most of the engineers used the same live load for both first floor and roof.

It was expected that the live load for the first floor to be different from that of the roof; however, only few engineers (2 projects) differentiated in the live load between first floor and roof according to the data provided. The use of the same value of live load for both floor slabs and roof is a reasonable assumption since roofs are normally accessible and may be used occasionally during the expected life of the building. In two projects, different live loads were specified for solid slabs and Hordi slabs. This is not warranted and represents lack of understanding of the provisions of the code.

3.5 Design Code

In most countries, the design engineer is guided by specifications called codes of practice. Engineering specifications are set up by various organizations to represent the minimum requirements necessary for the safety of the public. The codes specify design loads, allowable stresses, material quality, construction types, and other requirements related to building construction. In the USA, reinforced concrete design follows Building Code Requirements for Reinforced Concrete, widely known as the ACI code [ACI-318, 1995]. In Saudi Arabia, all the universities have adopted the ACI code in teaching courses dealing with design of concrete structures.

If the use of specific code is not mandated by law, structural engineers would be expected to employ the code which they are familiar with. This is most likely to be their native country code or the one they used during their university education. This clearly is reflected in the data shown in Figure 2. From this figure, 8 engineers out of the total reported using ACI Code, another 6 Arab (Syrian) Code and 3 used British Code. However, the majority reported basing their design on references other than code. References cited includes handbooks by Albhaeri and Helal, both from Egypt.

3.6 Analysis and Design Methods

3.6.1 Methods of Analysis

Structural Analysis is needed to determine the maximum load effects including moment, shear, axial load, and torsion or other load effects. Usually, performing the analysis of a structural frame or continuous construction is the most difficult and time-consuming part of the total design process.

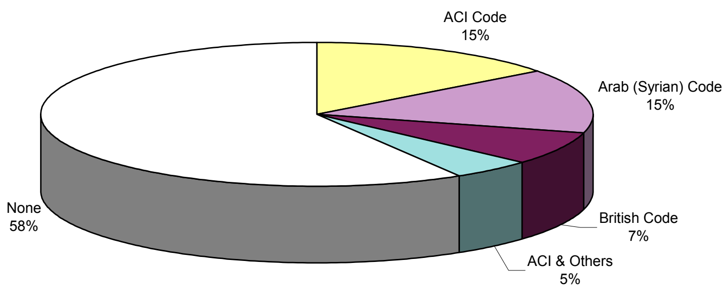

Figure 2: Code used for design

Since the layout of most of the small residential buildings is highly irregular, the use of simple and approximate methods for analysis is no longer possible. The engineer is required to use time-consuming procedures or structural analysis programs to find moments and shears at critical sections. Unfortunately, few engineers use such procedures or programs. Most of the engineers totally ignore continuity of the structure in their analysis as they treat the building frame as a collection of simply supported beams and concentrically loaded columns. In the study sample, only 12% of the engineers considered continuity in their analysis. This means that the vast majority (88%) were not performing any kind of structural analysis as part of the design process.

3.6.2 Design Methods

The design of a structure may be regarded as the process of selecting the proper materials and proportioning the different elements of the structure according to state-of-the-art engineering science and technology. In order to fulfill its purpose, the structure must meet the conditions of safety, serviceability, economy, and functionality. The design conditions and specifications represent the minimum requirements for protecting people against hazards. They may not always produce the best solutions in the practical sense, but they help to avoid the common errors, especially those related to the safety of the structures.

Two philosophies of design have long been prevalent in design codes. The working stress method, focusing on conditions at service loads, was the principle one used from the early 1900's. By the early 1980's, the transition has been made to the strength design method, focusing on conditions at loads greater than service loads when failure may be imminent. The strength design method is deemed conceptually more realistic to establish structural safety and economy. According to the data collected, 27 projects were designed by the working stress method, 12 projects were designed by the strength design method and two projects reported using mixtures of the two methods. Figure 3 shows the usage (in percentage) of the two design methods. The wide spread use of the working stress method reflects the condition of the practice where outdated methods are still predominant. This is in spite of the fact that the strength design method of the ACI code is the main design method taught by Saudi Universities for the last 20 years. These findings show the lack of proper link and interaction between engineering education at Saudi Universities and local practice.

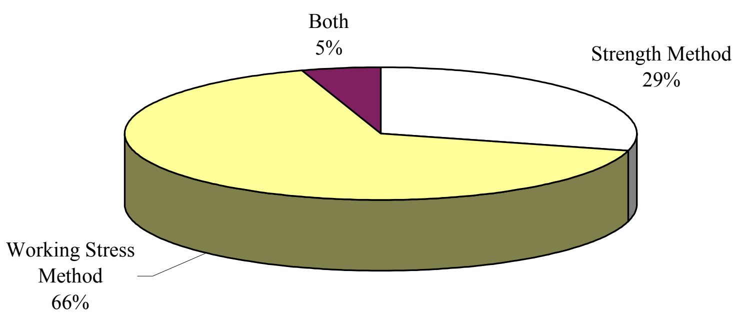

Figure 3: Design method used

3.7 Design Assumptions and Stresses

For concrete, several strength classes are possible and available in the local market. For steel, only 420 and 280 strength grades are available locally. Typically, steel with 420 MPa yield strength is used for main reinforcement and 280 MPa for secondary and shear reinforcement.

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3.7.1 Concrete and steel strength

The minimum crushing strength of concrete f'_c for standard cylinder used in design of reinforced concrete elements should be 20 MPa [ACI, 1995]. For steel, the use of steel with yield strength f_y of 420 MPa is recommended for the main reinforcement since this grade of steel is widely available in the local market. The most common concrete strength used for the design of buildings from the study sample was 25 MPa concrete based on cubes tests which is equivalent to 20 MPa based on standard cylinder.

The steel specified when designing these buildings was grade 60 (f_y = 420 MPa) which was used in about 87 % of the cases which is logical with the fact that this is the Grade of steel available in local market today. However, 13 % of the total specified f_y less than 420 MPa which is wasteful and indicate that some designers lack the awareness of the properties of material available in the local market.

3.7.2 Bearing capacity

Bearing capacity of soil is very important factor for designing foundations. Bearing capacity depends on the type and characteristic of soil and could vary from one location to another. According to the data collected, 90 % of cases used bearing capacity of 200 kN/m^2 , 7 % used bearing capacity of 150 kN/m^2 , and only 3 % used bearing capacity of 250 kN/m^2. The low bearing capacity specified may be attributed to the weak soil in Riyadh and partly due to a decision by designers to be conservative as no soil investigation is done for construction of small buildings.

4. ANALYSIS AND CRITIQUE

The structural design practice in the Kingdom specially as it relates to housing sector is inflected by many shortcomings and problems. Some of these problems are also inflecting the architectural/ engineering (A/E) practice in general. The following analysis and critiques are directed towards some of the factors believed to have bearing on the structural design practice and the housing sector.

4.1 Legal and Administrative Aspects

Many problems with structural engineering practice in the Kingdom relating to residential construction stem mainly from the lack of national building code governing the design and construction of such buildings. The multitudes of codes and experiences utilized in the structural design is a manifestation of this problem and point to the need for national building code to standardize the design process and spells out the legal obligations and liabilities of the parties involved in design and construction. Significant improvement in the design practice will only be possible with the development and implementation of a national Saudi Building Code.

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Another important issue towards professionalism in the engineering practice is the professional registration. Professional licensing for the design engineer and liability issues are not addressed in the current engineering practice in the Kingdom and as a result unqualified engineers do work on design in many consulting offices [Zaalouk, 1992]. This practice leads to deficiencies in design and encourages wasteful over-design. The need to maintain professional registration will encourage engineers to keep up to date with the current knowledge in their field. This will reduce the use of outmoded design methods and reliance on outdated knowledge.

Continuing education for practicing engineers and orientation and training for new university graduates and expatriates who are about to join the engineering practice in the Kingdom for the first time should be part of the professional licensing requirements. This will assure that practicing engineers are qualified, up-to-date and familiar with the local conditions, materials and problems. Saudi Universities should play essential part in the education and training programs. As it stands now, engineering education and engineering practice are not coherent.

The design problems in the housing sector are aggravated by the fact that most of A/E design offices serving the local residential market are small offices operating in very competitive environment. The resulting low design fees do not encourage sound professional practice. It also does not favor the growth and sustenance of quality design offices. The introduction of Saudi Building Code coupled by mandatory professional registration and training will help professionalism in the practice to take roots. With time, this will reduce and hopefully eliminate the low design fees which are manifestation of lack of professional conduct and/or outright unethical practice.

In the mean time and until a Saudi Design Code is approved and implemented, the Municipality could take some steps to rectify the situation. A formal written procedure or guidelines for the preparation of the design drawings and data and details to be included should be given by the Municipality. This will eliminate the widely variation in style, format and level of details observed for the design drawings collected for this study. The Engineering Committee could start and promote professional registration in the various engineering fields.

4.2 Technical Aspects

Specified design parameters such as dead and live loads, strength of materials and soil bearing capacity are reasonably estimated and specified in most designs. In the limited cases where these parameters are not adequately specified, the combined package of Saudi Building Code, orientation and training of engineers which should be part of any professional licensing requirements would essentially solve this problem.

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The integrity and adequacy of the structural design process itself may be more difficult to rectify. As mention earlier, structural analysis is needed to determine the maximum effects of loads. Usually, performing the analysis of a structural frame or continuous construction is the most difficult and time-consuming part of the total design process. The results from this study clearly show that limited, if any, structural analysis was performed for the design of small residential buildings. Since the layout is highly irregular, the use of simple and approximate methods for analysis is no longer possible. The engineer is required to use time-consuming procedures or structural analysis programs to find moment and shear at critical sections. Unfortunately, few engineers use such procedures or programs with most engineers totally ignore continuity of the structure in their analysis. They treat the building frame as a collection of simply supported beams and concentrically loaded columns with only 12% of engineers considering continuity in the analysis. Clearly, this is done to simplify the analysis and to save time which are dictated by incompetence and low design fees.

The other important factor is technical in nature. The column layout of most buildings is highly irregular despite the wide use of joist slab which is supposed to improve and simplify the structural layout. This is the reason for the lack of any systematic beam and joist layout. The haphazard choice of beams and joists are affected by the following factors:

1. The different floor layouts between ground floor and the first floor and the golden rule by architects and engineers to hide columns in the walls.

2. The large disparity in room sizes. For functional consideration, large room sizes have to be put next to smaller rooms and corridors.

3. The predominate use of normal-weight concrete blocks for walls. In the survey, almost all projects used concrete blocks for all curtain walls as well as interior partitions. The use of these heavy partitions is normally accompanied by the use of supporting beams underneath them. This appears to be one of the main reasons for the high irregularity of the framing system observed in the structural design of residential buildings. Efforts should be directed toward utilizing lighter materials for the interior partitions without sacrificing the economy and other advantages of such as sound insulation of the heavy materials.

4. The common use of depressed solid slab for bathrooms to allow for hiding all plumbing fixture in the slab. This clearly affects the continuity of the Hordi slab.

Research is needed to improve the design and detailing practice of the RC frame system. Substantial cost saving can be realized if one can make essential improvements to the plan of the structural system. Improving the plan layout should result in regular grid having approximately equal spans. As a result, continuity can be utilized, smaller sizes can be used resulting in significant saving of materials and reduction in construction time.

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4.3 Fostering Development and Innovation

The limited number of materials and methods used in housing construction in Riyadh point to the need to foster development and innovation in the residential construction industry. Many innovative techniques and methods may have difficult time before being accepted by the owner-builders. As it stands now, nobody seems ready tackle the problems of housing. The Real-State Development Bank, Ministry of Public Work and Housing, and KACST all are content to sit on the sideline and watch. Therefore, effort should be directed toward establishing a private (or semi-government) nonprofit institute or organization with the task of promoting innovation and funding research in the area of housing. It should also serve as data bank on all aspect of the building construction in Saudi Arabia. This agency or institute can cooperate with local expertise in the universities and the private sector to provide solution to the many problems faced by the local building industry. It can contribute greatly to the education of home-owners as of the proper construction techniques and methods through videos, local media and other tools. Such agencies and institutes are found in many countries. The establishment of similar entity in the Kingdom was advocated by Al-Hussayen [1980] over 20 years ago.

5. CONCLUSIONS AND RECOMMENDATION

In this paper, an overview of the structural design practice was given based on analysis of data from 41 design projects representing typical design practice of new construction in Riyadh. The data highlighted the lack of uniformity in the design of residential buildings in Riyadh. Many codes and outdated references were used in design. Gross and wasteful simplifications such as ignoring continuity were a common practice. These results clearly indicate the urgent need for Saudi Building Code which provide for comprehensive treatment of technical and legal aspects of design and construction of residential buildings in the Kingdom. Professional registration and continuing education and training and increased participation of Saudi engineers were highlighted. Also, the need to promote research and innovation in the residential construction industry was particularly emphasized.

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