A FLEXIBLE AND FUNCTIONAL REINFORCED MASONRY CONSTRUCTION SYSTEM FOR RESIDENTIAL APARTMENTS

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ABSTRACT

The use of reinforced masonry is negligible when compared to any other construction techniques in Turkey. Traditional construction techniques are generally framed structues or frames combined with shear walls in which all have plastered and painted clay brick infill walls and facades. This paper introduces the use of reinforced masonry and focuses on the advantages of using reinforced masonry against framed structure models with clay brick infill walls with the help of an award winning project in Turkey named NP12. NP12 as the first residential 4 storey reinforced masonry structure complex in Turkey plays an important role in introducing this method of construction. The architectural advantages of using this system, its seismic behaviour, insulation, combination of different materials, flexibility and structural code requirements are presented.

KEYWORDS

Reinforced masonry, insulation, flexibility

1 INTRODUCTION

Masonry construction has its beginnings in the earliest of human settlements. Review of the historic use of masonry can help to place present-day construction in perspective and impart inspiration from the past.

A building must not only be structurally safe but also must have functionality in order to be habitable. Functionality can be broadly defined as the architectural requirements of a building along with comfort requirements such as sound and thermal insulation. The functional characteristics of a building constructed by conventional methods such as steel and concrete construction is provided after the structural frame of the building is constructed. Early masonry construction, on the other hand, had the advantage of working with local materials as well as providing functionality to a building as it was built. Many materials were used for masonry

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construction and use of local materials were the first ones to be considered. In modern cities, stones from nearby quarries, engineered blocks using cement and clay and even glass can be used as masonry units.

The most common masonry materials used today are made from stone, clay, calcium silicate and cement. Masonry units can be mass-produced in many size, shape and colours, that can be engineered to required strength levels and architecturally formed to the desired pattern and texture. [Drysdale *et al.* 1999]

This paper focuses on the use of concrete masonry units in urban construction and highlights the architectural, economical and environmental benefits of the use of reinforced masonry construction method when compared to traditional construction techniques in Turkey.

2 CONCRETE MASONRY UNITS

The production of concrete masonry units began when cements with reliable characteristics were produced. Developments in material handling have resulted in the fully automated machines that can mass-produce masonry units with a variety of size, shape and architectural textures and colours. Modern concrete blocks are manufactured by vibrating a mixture of portland cement, sand and aggregate in a mould under pressure. [Drysdale *et al.* 1999]

3 ADVANTAGES OF USING MASONRY IN TURKEY

3.1 Production and Construction Quality

The definition “traditional construction in Turkey” briefly means buildings with reinforced concrete frames or frames with shear walls. The architectural partitions and facades are formed by clay bricks that are plastered and painted with different textures. In the past few years, constructors began to insulate new built structures with polystyrene based foamboards. A traditioanl construction is shown on the right in ‘Fig. 1’ while a very common thermal insulation applied building is on the left.

Figure 1: Polystyrene based foam used in insulating buildings for thermal effects on a clay brick facade wall on the left and before insulation and plastering on the right.

Concrete masonry blocks with their load bearing capability, different colours and textures selection, production quality since they are factory based products, ease of application and construction speed, are very efficient building materials. Reinforced masonry allows the designers to satisfy architectural demands without any major difference when compared to the traditional construction technics in Turkey.

3.2 Architectural Demands and An Efficient System "NP 12"

A building can meet the requirements of all the structural codes and standards but may still fail to provide functionality. The physical, economic and psychological well being of the occupants are related to the functional design of the building. Satisfactory habitation conditions and building aesthetics must be provided to meet the requirements of the needs of the occupants. Changing climate conditions, evolving social awareness and economic considerations have also resulted in functional design considerations which takes into account not only the occupants of the building but also the economic and social impact of the building to its community. Sustainability defines the consideration for the efficient use and longevity of vital supplies for human ecological support systems. The demand for energy and the pollution that is created for the generation of the energy, along with the sources of the raw materials used to construct a building are important considerations for sustainability.

3.2.1. NP 12:An Award Winning Residental Project – An Example of a Reinforced Masonry Building

Nafizpaşa Konakları; also known as NP12, is an award winning residential Project that includes 6 semi-detached 4 storey buildings with a basement and a garret. The complex is a good example of masonry construction that highlights all the benefits of using masonry units as the preferred structural and architectural method of construction. The complex consists of more than 300 varieties of internal wall arrangements within the building shell to cater for the demands of ocuupiers. This has been achieved without changing the fixed sub and superstructure.

With its unique variable storey plans and stylish facades of masonry blocks in corporation with steel framed balconies with timber decks, NP 12 won two architectural awards while it was exhibited on many activities.
The awards are; "YEM Architects first building" a national competition evaluating the functionality of the structures and "X.National Architectural Exibithion-Structural Award" which is given by the Chamber of Arctitects of Turkey in every two years.

With the help of the awards won, NP 12 was exhibited in DAM Frankfurt am Main/GG,"becoming Istanbul" and Europian Union Price for Contemporary Architecture Mies van der Rohe Award in 2007. It was also exhibited in the IX. and X. National Architectural Exhibitions in 2004 and 2006. Many articles about the project were published in national architecture magazines in Turkey from 2003 to 2008.

The questions shaping the design centered on the relationship between what was relevant to construction and what was relevant to life. What kind of a constant structure is needed that would accommodate both standard and mass production, meanwhile allowing flexible options for the different lifestyles of its unknown user? What was relevant to construction was made constant, and shaped into a box (with standard structural characteristics of interior-exterior, emptiness-fullness) that could be replicated? While this constant structure displayed invariable, inflexible external characteristics, its interior was designed to accommodate the lives of those with different preferences, thus making the flexibility possible.

The creation of the flexible design was based on the characteristics of the constant characteristics, and that its emancipation was achieved through limitations and restrictions that were the inevitable byproducts of the design process. All components (space, carrying frame, mechanical and electrical components) were part of the flexible design as a whole. The constant structure is made of a carrier box with adjoining steel and wood components. The common wall dividing the shell into two residential units transforms into a utility wall poviding a common functional aspect of the house. All structural voids on the shell (including the utility shaft voids) have been fixed in place in a way that would accommodate the different floor plans. Even when the function of any given space changed from being that of a living room, to a bedroom, or to a bathroom, the design mentioned above ensured that the heating system provided the desired level of comfort. The internal functions of a flexible house are divided in to two parts; spaces requiring plumbing infrastructure and living areas. The wet spaces linked to the utility wall in each floor plan attain a flexibility in size and quantity that's limited by this wall. By reserving accessible permanent shafts in the utility wall, standards allowing ease of formation and use of wet spaces have been achieved. The aggregation of wet spaces around the blind internal surfaces of the shell enables the use of spaces facing the exterior as living areas that can be divided according to different needs. A similar arrangement was created for the electrical infrastructure serving the living area. Shafts, structural voids, and empty ducts were set aside, forming an infrastructure that could meet the changing demands with time. Within the principles determined by the constant shell, each floor plan was transformed into living areas with flexible characteristics. With the walls forming the box evolving into a carrier system, which eliminates the need for lining, creates structural voids providing inherent advantages for building physics and utility units, and enables quick implementation.

Having constant and flexible characteristics, the building has been implemented in two phases. In the first phase the implementing contractor builds the permanent structures of the building. In the second phase, the customer determines the flexible components and shapes the internal space with the help of the contractor or another architect of their choice. NP12 apartments were constructed with hollow core concrete masonry units with a special interlocking system. The innovative interlocking system further reduced the construction time to build the walls by conventional masonry units by interlayer grouting. ‘Figure 2’ shows the interlocking masonry unit.

Figure 2. Interlocking masonry unit.

Prestressed 15 cm. thick hollow core slabs with 5 cm. topping spanning 8 meters were used at each storey. The garret was composed of masonry walls and steel framed roof frames with timber covering and clay tiles. At two storeys, steel framed balconies with timber slabs were attached to the buildings and every building had steel and timber composite sun curtains attached at one facade. Use of steel and wood together with masonry was succesfully applied in NP12. 'Figure 3' shows typical hollow core slab, masonry wall connection.

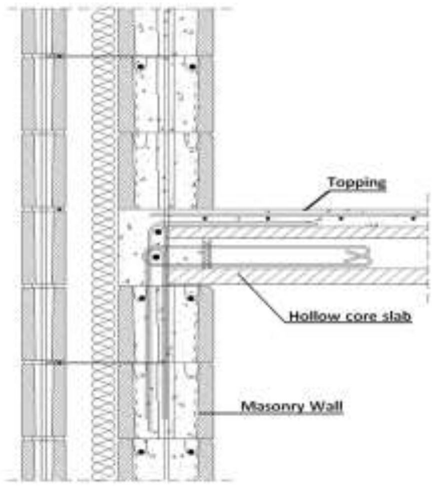

Figure 3: Typical hollow core slab, masonry wall connection.

Use of masonry enabled fast completion of the project. Other advantages of masonry were its thermal and sound insulation capacities and its capacity to simultaneously satisfy architectural and structural demands of the building. The use of interlocking blocks eliminated mortar and plaster in the construction process while adding speed. By filling the cores of the blocks with concrete, higher capacity and stability was achieved against lateral loads so that safety in high earthquake risk areas was not compromised. Shear walls were created by the use of masonry without the need for formworks. This system needs no formwork at all while the traditional construction methods rely on good shutters.

In NP12 houses, two masonry wall layers were used. The first layer was the 20 cm. thick loadbearing wall and the second layer was the outer layer, 9 cm. thick for creating an insulation layer and acting as a decorative facade. The space between the two layers provided air space for ventilation, contained thermal insulation material and provided sound insulation. 'Figure 4' displays the cross section of the multi whyte wall system. The main loadbearing walls are the in-lay walls as well. The architecture formed by masonry is free of columns and beams while an area of 80 m^2's is designed.

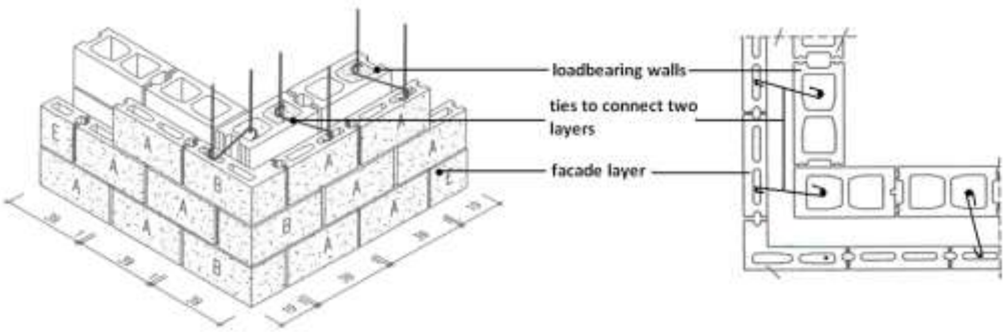

Figure 4. Multi wythe wall system.

'Figure 5' displays a variable plan design of one storey of NP 12 houses. In NP12, a unique architectural design is offered to potential clients by offering them the option to select the architectural floor-plan for each floor within the shell created by masonry walls. The prefabricated and modular nature of the construction materials used in NP12 provided the architects and the structural engineers the tool to custom design the building based on occupant's preferences. The buildings are based on a modular system that superimposes the structural elements forming the buildings and then providing within this system the selected architectural layout where masonry shell of the building provides the structural framework within which the demanded architectural layout could be implemented.

Figure 5: The static plan on the left can be transformed to the following plans by the occupants.

3.3. Advantages of Reinforced Masonry Compared to Traditional Construction Methods in Turkey

The advantages of the use of reinforced masonry started to manifest itself following the completion and occupancy of the NP12 houses, as low costs of heating and cooling. These effects are the direct consequences of masonry construction.
General properties and functional advantages of masonry construction are:

- Masonry walls do not require plaster, paint and maintenance. Traditional construction has infill walls and facades that needs plastering and painting with maintenance in Turkey.
- Fire resistance.
- Thermal insulation. By creating a structural shell surrounded by a thermal insulation shell, loss of heat and energy is obstructed. The system allows to

create a ventilation layer that prevents the interior surfaces from condensation and moisture. ‘Figure 6’ shows the typical shells.

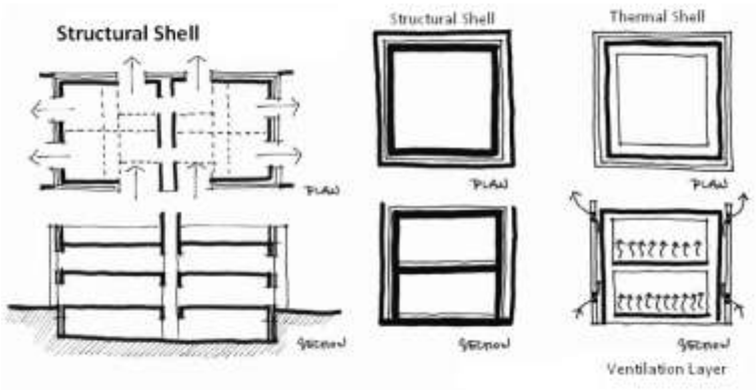

Figure 6. Shell concept.

– Construction speed as high as 18 m^2/day by using mortarless interlocking blocks. A team of three workers can construct, place the reinforcing bars, prepare temporary supports for the wall not to collapse while concreting, pour the infill concrete and replace the supports. For this process with traditional masonry in Turkey, the same team can only construct up to 8 m^2/day. These values are obtained in the NP 12 project. Time needed to complete the exterior walls, plastering, insulation and painting in the traditional construction is even much more than finishing the whole load bearing walls and the facade layer with the system used in NP 12. This points that the system used in NP 12 is economical when a short time schedule is followed.

The thermal performance of a masonry wall depends on its thermal resistance (R-value) as well as the thermal mass characteristics of the wall. The R-value is determined by the size and type of masonry unit, type and location of insulation, finish materials and density of masonry. Lower density concretes result in higher R-values than higher density concretes. [TEK 6-11]

The advantages of concrete masonry include reducing the amplitude of energy demand. In exterior walls, concrete masonry delays heat transfer through the exterior envelope. The mass of walls absorbs and stores energy, thus further contributing to shifting demand and improving thermal energy. Interior concrete masonry, such as partitions, stair walls, provide greater comfort by moderating temperature fluctuations through thermal mass, while at the same time providing all of the other benefits of concrete masonry. [TEK 6-3]

Table 1 shows the thermal insulation values for NP 12 and a traditional structure with polystyrene foamboard insulation according to TS 825, the code for thermal insulation in Turkey. For NP 12 and a traditional structure the prefered wall layers are shown on ‘Fig 7’. The difference in the polystrene thickness is the most effective factor. The most prefered system is to cover the cladding walls with 2cm. thick polystrene foamboards and 2cm. plaster on it. A 2 cm plastering application on the interior spaces is also done. This system has no air ventilation and polystrene boards limits air diffusion up to a point, that causes moist at interior spaces while NP 12 wall system has a ventilation layer that limits moisture.

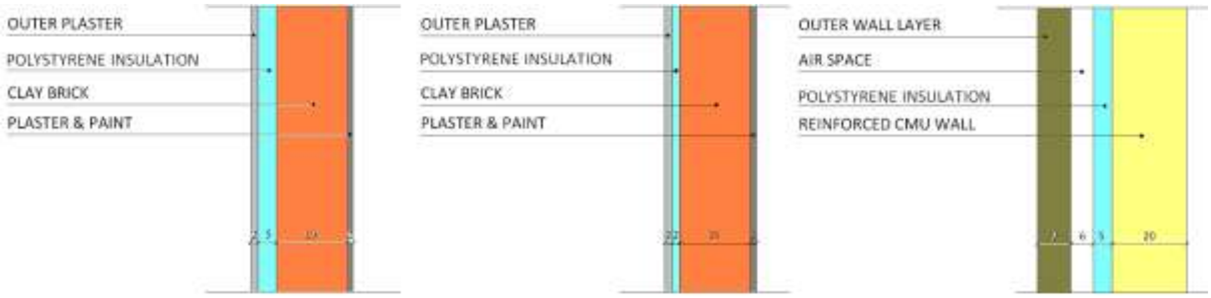

Figure 7. Types of walls to be compared. Left traditional wall with 5cm. insulation, middle traditional wall with 2 cm. insulation, right NP 12's wall system.

Table 1. Thermal insulation differences between compared systems.

	Traditional 2cm. insulated	Traditional 5cm. insulated	NP 12 System
Thermal transmittance values for walls	0,5791	0,3667	0,3853

Thermal transmittance values must be smaller than 0,60 according to TS 825. This value reflects the thermal performance of walls

3.3.1. Architectural advantages of reinforced masonry

The capability to use the structural system as the functional system resulted in the efficient design of NP12 project. Use of masonry resulted in a structures adapt with their surrounding. 'Figures 8 to 10' show the completed structures. The modularity of the materials used in the system allowed to combine steel framed roof and balconies and timber sunshades into the project.

Figure 8. Adaptation to nature.

Figure 9. Timber floors and sun barriers in conjunction with masonry walls.

Figure 10. Harmony of natural materials.

3.4. Structural Considerations.

The Turkish Seismic Code released in 2006, limits the use of masonry in seismic zones and specifies total number of storeys and wall thicknesses that must be used in different seismic zones. The regulations are based on wall lengths, total wall areas and ratios of wall cross sections to total building areas. There are not any other considerations about reinforced masonry structures in the code. In the design process of NP 12, other than the national codes, UBC 1997 and ACI 530 were used. If NP 12 houses were built in traditional masonry there would be less building height and much smaller openings and windows. Table 2 shows the Turkish Seismic Code regulations NP 12 would deal with, in case of being built unreinforced.

Table 2: Comparison of NP 12 with traditional masonry systems in Turkey.

	NP 12 (used values)	Masonry regulations
Structural Behaviour Factor (R)	2	2
Max. Number of storeys permitted for 1st. Seismic zone	4st*3m	2st.*3m.
Min. Thicknesses of load-bearing walls	20 cm.	25 cm.
Min. Total length of	0,1 m/m^2	0,2*I m/m^2

load bearing walls.(ratio of wall length to gross floor area)		(I=building importance factor)
Max. Unsupported load-bearing wall length	10,2 m	5,5 m.
Max. openings	2,4 m.	3 m.

Since the designers use high earthquake loads in analysing the reinforced masonry structures due to the code regulations, these buildings are very rigid and do not need ductility. This method of design turns the NP 12 project into an earthquake resistant masonry structure in the 1st seismic zone according to the Turkish Earthquake Code 2006. The same code forces the designer to choose a very ductile system in the traditional construction methods in Turkey. This brings a lot of components into the analysis process and makes it a complex issue thus reinforced masonry is easy to analyse.

4. CONCLUSION

The traditional construction techniques in Turkey has more components in both analysis and construction processes. Reinforced masonry, by its typical materials and high quality products, performs as a better solution of construction. This system combines the advantages of traditional masonry and reinforced concrete strucutures in one process.

The traditional construction techniques in Turkey are criticized and to bring high quality into the construction processes new codes and laws are enacted. Because of the latest enforcements of laws elaborate seismic design of buildings and increasing insulation materials qualities increased the construction costs and construction times. The aim is to reduce the running costs by adding quality while this will increase the investment costs. But still masonry structures, because of the materials nature, have lower running costs that will put masonry in a more advantageous position in Turkey.

There are still doubts on how to design and apply reinforced masonry structures in Turkey. With the new codes to be released, this method may be realised by designers and in the near future we can see more of these award winning projects all around the country.

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