International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 4, April - 2013

Reinforced Concrete Beam's Contribution On Sustainable Buildings

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Abstract

Construction industry is going toward more group thinking among construction managers and designers. In this way reconsideration in the design stage to achieve more sustainable structures are needed. Changing some usual shapes of structural members can help with energy efficiency and sustainability. Additionally, to reduce the time and cost of projects in the construction phase, appropriate cooperation between project managers and designers is a necessity. This study aims to integrate architectural and structural demands in the building. For a sustainable design of structure wide beams with the same bearing capacity as normal beams are popular among building providers. Easy formwork, lower depth to allow services to run under the floor, long span, minimum structural depth to provide inter-story height, possibility to use flying forms, and consequently good cost and time solutions makes wide beams in priority. Discussion on the advantages of using wide beams as a common member of structures in semi seismic areas reveals more efficiency of these members.

1. Introduction

High humidity along with low temperature variations are the main features of tropical climates throughout the year. Climatic conditions in tropical countries influence architecture and structural design of the construction industry. A common task for designers is to be aware of the demands on their plans. Building structures serve in residential and nonresidential categories which need management and maintenance during their life cycle. Sustainable construction for buildings needs to be well defined architecturally and structurally to resist the applied loads under diverse conditions as well as effective performance.

From the architectural point of view, building requirement is mostly landscape influenced by the layout and lighting. As it is observed in many historical buildings, a properly architectural designed structure or building encourages no changes induced by environment and humanity. In a research [1] from the architectural point of view, taking advantage of solar radiation and sky luminance, ventilation, human thermal comfort, and green spaces in public areas in tropical humid climate are discussed and considerations of the local environment were highlighted.

Other researchers also tried to use special equipments on the ceilings for ventilation and cooling in conditions of high ambient temperature coupled with humidity.

From the structural point of view, availability of materials, environmental resistance, durability, and even skilled manpower lead to a sustainable structure. Experiments [2] have shown that concrete which is a strong durable building material when reinforced by steel has revealed good behavior under different types of loading and environmental conditions. Steel members reduce the total weight of a structure, but in case of fire resistance and corrosive condition are not as fine as reinforced concrete members. Structural elements are normally divided into beams, columns, slabs, and walls that are important in the construction industry for their load bearing. However, the characteristics of these elements such as sound and energy insulation can highly influence their utilization in different climatic conditions.

Researchers [3] have studied the thermal performance of insulated roof slabs in tropical climates. It was indicated that the thermal performance of reinforced concrete roof slabs can be significantly improved with resistive insulation in order to use these slabs as an ideal alternative to conventional light

weight roofs which are susceptible to uplifting during tropical cyclones. In this paper, reinforced concrete wide beam as a special type of structural members compatible with tropical humid climate is studied. The compatibility with wide beams with slab height to run maneuver on insulation improvement and material availability for concrete structures are noticed in this study.

Because of the different geometry of reinforced concrete wide beams, the width over height ratio of about three, they are also called shallow beams, wide band beams, or thickened slab bands. The advantages of reinforced concrete wide beams, here called wide beams, are easy formwork, lower depth to allow services to run under the floor, long span, minimum structural depth to provide inter-story height, possibility to use flying forms, and consequently good cost/time solution. Therefore, several points of view in this paper intend to contribute about a sustainable structure using wide beams.

Scope of study

This paper focuses on the performance of a normal reinforced concrete beam and a reinforced concrete wide beam designed with the same bearing capacity based on EC2 (Design of concrete structures). The size of normal beam is taken as the most casual size of the beams which is about 300mm by 300mm and for a similar use a wide beam of size 250mm by 500mm is selected. In terms of material and condition everything is same for both. It is important to be reminded that from ACI 318 shear provisions a "Wide Beam" has a width to height ratio of at least two[5]. In a 3m span with assume of ultimate load design moment of 165KN-m, Fck=25N/mm² and Fyk = 500 N/mm² design resulted reinforcement and geometry are shown in figure 1 and 2.

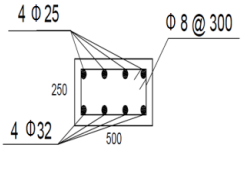

Figure1. Wide beam

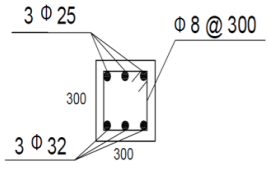

Figure 2. Normal beam

2. Structural Performance

Concrete compression strength is high, but the tensile strength of concrete is very low. Steel bars as reinforcement in wide beams are designed to carry the tensile forces. Concrete is compatible with different weather conditions, but the corrosion of steel in concrete induced by chloride ion contamination is a major problem in environments with frequent wetting [6]. Concrete resistivity and the corrosion rate of steel bars can be appropriately improved using blended cements [7].

To provide enough ductility, beams are commonly designed to be flexural critical. Principal stresses due to tension and compression forces in a concrete beam are shown. in Fig.3(a). Depending on shear critical or flexure critical design of a beam, cracks appear. If the beam design is flexure critical, under loading when concrete in tension reaches its highest tension capacity cracks start from the mid-span from the bottom of the beam to the neutral axes. When cracks are started, longitudinal reinforcement would carry the flexure. In case of shear critical after concrete experiences its final capacity, mostly higher shear strength is in the mid-depth of the beam, shear reinforcement resists the stress. The role of reinforcement in concrete is presented in Fig 3(b).

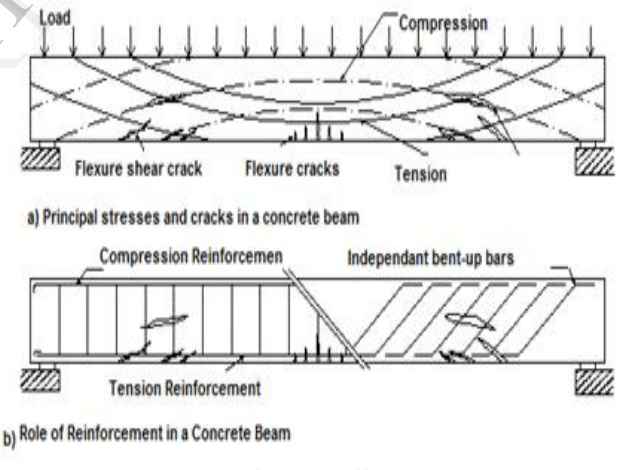

Figure 3. Stress and reinforcement effects in a concrete beam

Large cross-sectional area of wide beams contribute to the shear resistance and only some numbers of stirrup legs in cross section and through the beam help to improve shear capacity of wide beams [8]. In slabs a mesh of transversal and longitudinal reinforcement is applied to resist shear which is not as effective as stirrups and bent-up bars that pass through the member height. Beam to column connections of wide beams showed poor behaviour for high-seismicity countries [9].

Wide beams have been in common-use for countries of low to moderate-seismicity like Malaysia, Spain, Italy, and Australia[10]. However, regarding the

geometry of wide beams, there are some recent researches in order to improve wide beams capacity for different regions. Stirrups with some legs may cause to congestion of reinforcement in a system of wide beams and slabs and make it more difficult to be reinforced for shear. Independent bent-up bars have been tested and experiments revealed a good shear performance of this new type of shear reinforcement [11]. Ease of installation and acceptable shear resistance of independent bent-up bars because of the provided anchorage area in these structures can be practically useful to reinforce wide beams and slabs for punching shear and also applicable for pre-cast beams and slabs.

3. Architectural Performance

In design of buildings, modern architectural constraints are pushing designers to provide longer clear spans at a reasonable cost. At the same time, there is a need to minimize the overall structural slab depth to achieve more floor clear height, which can be achieved through the use of either shallow wide beams or flat plate slabs [2]. In this way shallow concrete beams are suggested as a method with several merits.

A wide-beam system processes many advantages from the architectural and economical considerations because of its special nature. The potential benefits include reduction in formwork, simplicity of repetition thereby accelerating the construction speed, and decrease in story height leading to a reduction in the cost of construction. With these and other advantages, the buildings and composite structural systems involving wide beam frames have become very popular as the gravity load-resisting frames in non seismicity regions. In the meantime, the potential advantages and applications of the wide beam systems in a lateral load-resisting structure are often ignored due to the lack of understanding of its seismic performance [5].

Floor Height

Reduced structural depth enhances both the appearance and economy of concrete parking structures. In some cases, depth reduction is an essential factor in meeting code height restrictions. For underground parking structures, reduced depth reduces excavation and shoring costs as well as improving parking efficiency due to shorter ramps. There is no doubt that the relationship between daylight versus height will not change, So with higher floor height we can use more natural energy of day light and decrease in using electricity(Fig.4).

Figure 4. Normal beam in parking area

Enhanced Lighting and Patron Security

The wide beam spacing and flat surfaces provided by cast-in-place parking structures enhance the installation and efficiency of the lighting system. This results in improved aesthetics and enhanced patron security. By implementing wide beams in structural, ceiling will become flatter as it is shown in Fig.5 in comparing to deep and T shape beams, therefore to plaster and paint this kind of areas less time and manpower is needed.

Figure 5. Wide Beam for a meeting hall

Natural ventilation

In areas with more flat roofs it is easy to feel there is more natural air flow than ceiling with deep beam edges and deep joists. It helps to use natural wind or breeze as a renewable energy in areas with permanent or temporary wind. Also less air movement can result in more carbon dioxide accumulation especially in parking buildings .Avoid making Heat Islands under the ceiling; Heat islands are microclimate regions with temperatures higher than in their surroundings, they directly influence the air conditioning consumption of electric energy.

It is worth mentioning that the rate of ventilation in open spaces may arise or may lower the heat islands' temperature. These areas can effect on thermal comfort of the occupants of the building. Better natural air flow is an advantage for ceilings with wide beam. In the humid tropics, air renewal brings benefits not only because it incorporates air masses with lower temperature, but because the renewed air brings less relative humidity than in the case of inhabited regions.

4. Sustainability

According to Green Building Index a sustainable structure expected to cover 6 main factors (Energy Efficiency (EE), indoor Environmental Quality (EQ), Sustainable site planning & Management (SM), Materials & Resources (MR), Water Efficiency (WE), Innovation (IN) [9]. In addition, the main factors in a sustainable construction are saving in cost and time and achieving higher quality. In this way modern methods of construction (MMC) are popular. Starting from design stage can help more in this goal. As a sustainable design in this paper using wide beams in concrete structure buildings suggested. By using this kind of components we have some achievements in above mentioned main three factors:

Time

Using wide beams in comparison with normal or deep beams needs less formwork because of its more simple geometry and modularity. Easier plastering due to almost same level of beam and slab can save more time in construction progress. In the reinforcement with bent up bars time decreased more, instead of using stirrups new suggestion provided an easier way for shear reinforcement with less time for assembling and less steel.

Cost

Less timber and manpower for formwork, saving in steel for reinforcement, less false ceiling and M & E channels are other aspects of saving in cost of construction. After construction (under service period) cost saving especially by using day light for inside lightening reduces using electrical lights. Less depth in comparison to other types of concrete beams can help workability without using plasticizers as an admixture .Shorten the vibration time can be another aspect which can decrease cost and time of construction. Figure 6 and 7 show fluctuation in piping, air condition channels and wiring systems which resulted in using deep beams. These kinds of beams don't allow services to run under the floor easily and causes more piping or channelling.

Figure6. The more fluctuation in channels for air - conditioning

Figure7. The More junction in M & E instruments

5. Performance Comparison

To compare the performance of a conventional and wide beams a 4m by 3m reinforced concrete structure bay chosen from a building with normal concrete beam and another same bay with same details and materials but using wide beams. Columns and slabs are designed with completely same assumption (Fig.8).

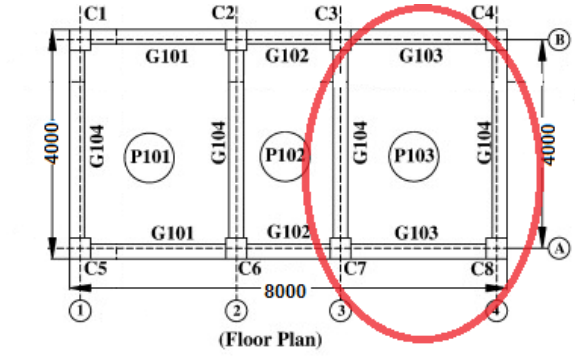

Figure 8. The bay chosen from plan (4m x 3m)

To compare the performance of normal concrete and wide beam 3 experts as contractor with critical quantity surveying have interviewed to assess the level of labor and time that each beam needed. Results in figures 9 and 10 Indicates that number of Labors in the mentioned bay for reinforcement for wide beam is 32Labor/Hour and for normal beam we need 36 Labor/Hour.

Form working normal beam uses 32 Labor/Hour but wide beam needs 30 Labor/Hour. For casting the concrete in wide beam we need 8 Labor/Hour and for normal beam also 8 Labor/Hour. Slabs and columns need almost same amount of manpower in both types of performance as it is shown in below figures.

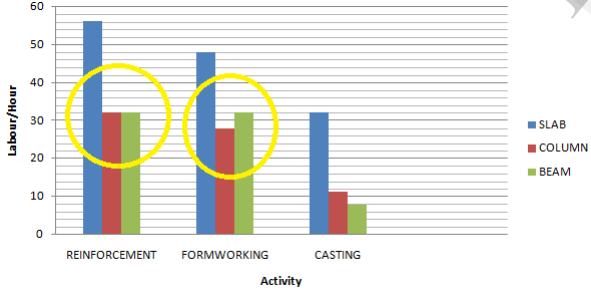

Figure 9. Performance of bay with Normal beam

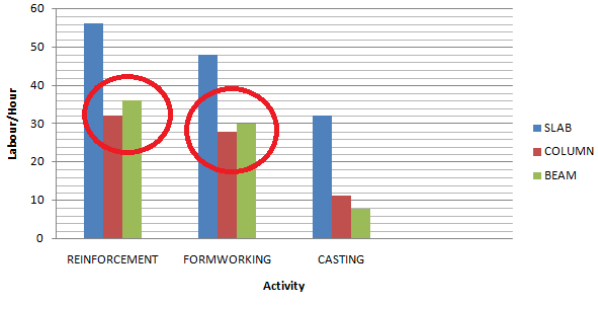

Figure 10. Performance of bay with Wide beam

6. Conclusion

Integration of designers and architects demands are sustained by some changes in building elements with climatic considerations. In tropical areas desire for using concrete structure is higher because concrete is a strong and durable material, particularly when reinforced by steel has revealed good behavior under different types of loading and environmental conditions. To optimize concrete members of a structure in terms of energy efficiency and sustainability beams as one of the most common members can be in priority. Structural and architectural assessments showed the merits of wide beams in comparing to normal beams.

They are also called shallow beams, wide band beams, or thickened slab bands. The advantages of reinforced concrete wide beams are easy formwork, lower depth to allow services to run under the floor, long span, minimum structural depth to provide inter-story height, possibility to use flying forms, and consequently good cost/time solutions. Thus, even with the same cost and time as normal beams because of architectural and sustainable benefits wide beams are suggested in semi seismic areas.

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