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A REVIEW TO THE STRUCTURAL BEHAVIOR OF REINFORCED CONCRETE WIDE BEAMS

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Abstract
Reinforced concrete wide beams have been utilized in building construction for a number of reasons, including reducing reinforcement congestion, reducing the amount of formwork needed, making replication easier, and lowering the storey height. Such beams can have sufficient cross-section areas with less depth than a system of slender beams with parallel distance in the plan and wide beam-column reinforced concrete connections, which have a high efficiency to withstand earthquake loads. This study tries to view the state of art in term of recent contributions about the structural wide beams. The past experience regarding these research programs is outlined with respect to the most important findings that gain throughout these studies.
Keywords (in English): Reinforced Concrete; Wide beam, Recent contributions and Structural Behavior..

1.Introduction

RC wide beams are described as beams with a large width-to-thickness ratio. These types of reinforced concrete beams are typically utilized as a low-cost transfer structural element with a shallow structural depth. In the structural building system, such elements are incorporated as secondary or primary load transfer. The presence of wide beams is therefore very useful for transferring loads from above tower portions to the free column spacing [1].

However, wide beams can have sufficient cross-section areas with less depth than a system of slender beams with parallel distance in the plan and the related RC connections. Such whole system is usually have a high efficiency to withstand earthquake loads [2]. Consequently, such structural members can be considered as simple and cost-effective alternatives which can provide structural depth that is shallower. As a result, wide beams are used to reduce floor height in warehouses, commercial buildings, and parking lots. In addition, there are many applicable building systems that can contain these members such as RC joist and ribbed slabs when its depth can equal or slightly higher of slab depth as shown in Figure 1 and Figure 2.

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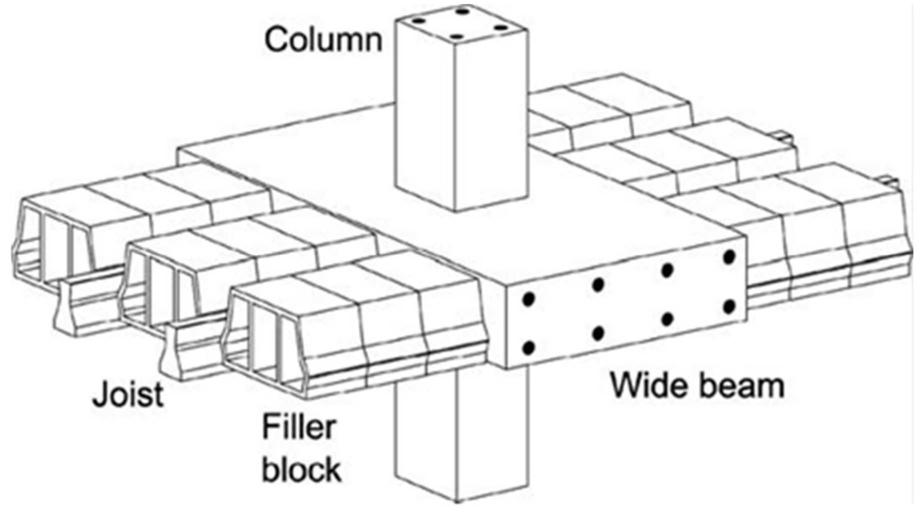


Figure 1. RC joist slab-wide beam systems [3].

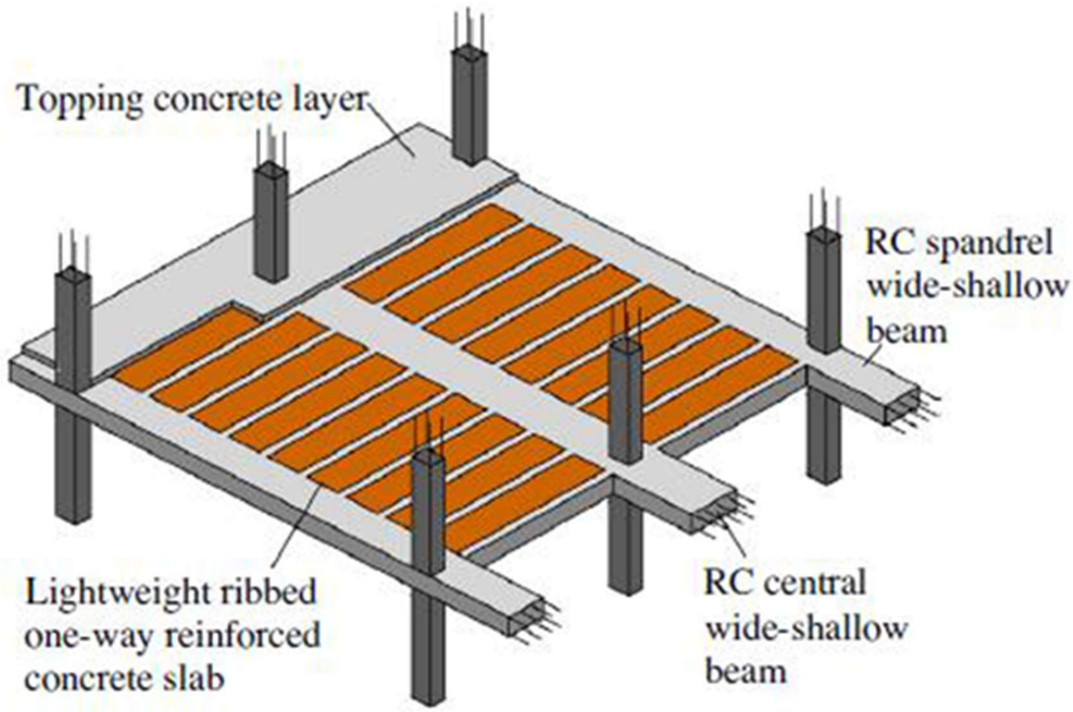


Figure 2. Ribbed one-way RC slab with wide beams [4]

Regarding the classification of these members, when the width of a beam exceeds the width of the column, or when the width exceeds twice the height of the beam, it is described as a wide beam. However, the current study tries to cover the most important recent contributions that dealt with the structural behavior of RC wide beams in order to give a descriptive view about this important topic.

2 Significance of The Study

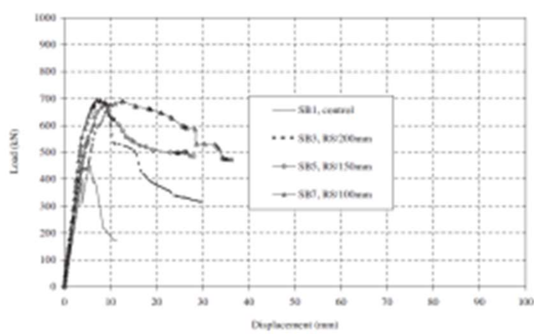
Collecting the reliable data about the structural behavior of RC wide beams is very crucial issue for any researcher for understanding the relevancy with the applicability of these structural members and to know the state of are to build reasonable starting point for his research program. In this way, the current paper presents a short review about the structural behavior of these beams.

3. Recent Contributions

The following are the most common research contributions that survived in the literature regarding wide RC beams.

Said and Elrakib, (2013) conducted out an experiment involving the casting and testing of nine reinforced concrete wide beams in order to assess the role of web vertical rebar. All beams have a compressive strength of 29 MPa, and the appropriate a/d "shear span to effective depth" for these specimens is 3. In addition, the spacing and yield stress of vertical reinforcement were chosen as significant parameters in that research contribution. The ultimate shear capacity and relevant ductility were used to describe the shear behavior.

The findings revealed that ultimate shear strength had a direct relationship with the relevant stirrup spacing, with the possibility to reach ultimate strength about 132%. Furthermore, once the steel grade is increased, such strength is grown seriously. Furthermore, the ductility response, on the other hand, increases as the spacing of stirrups and its grade increases. Figure (3) shows same reported results of that recent contribution.



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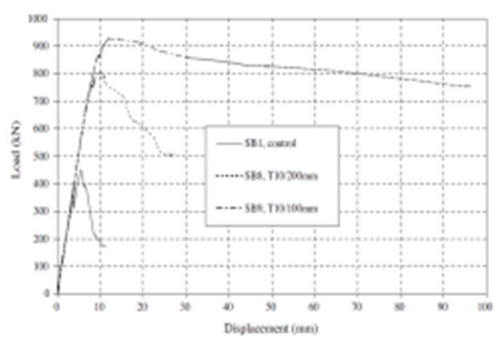
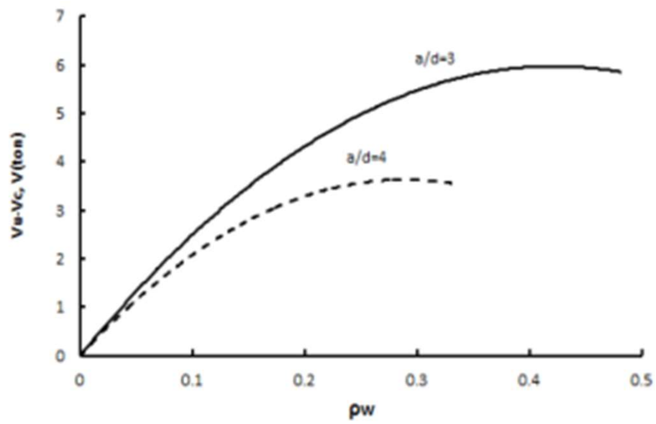


(b)

Figure 3. Load – displacement curves showing the effect of stirrups spacing in the work of Said and Elrakib, (2013) [1] : (a) Mild steel grades. (b) High steel grades.

To study the role of web rebar, Lotfy et al., (2014) [5] performed a research that comprised implementing and testing of 10 RC “wide beams. The ratio of web reinforcement, "stirrups spacing to depth ratio (s/d)", number of vertical branches, and (a/d) ratio were all variables in this study. Shear performance is also defined by ultimate shear strength, first cracking load, ductility behavior, and the relevant failure mechanism in that investigation. The basic conclusion drawn from the study's findings is that stirrups have a significant impact on ultimate capacity, mode of failure, and ductility. In addition, Figures (3 a) and (3 b) shows the effect of web reinforcement ratio while Figures (2 c) and (7 d) view s/d ratio effects.



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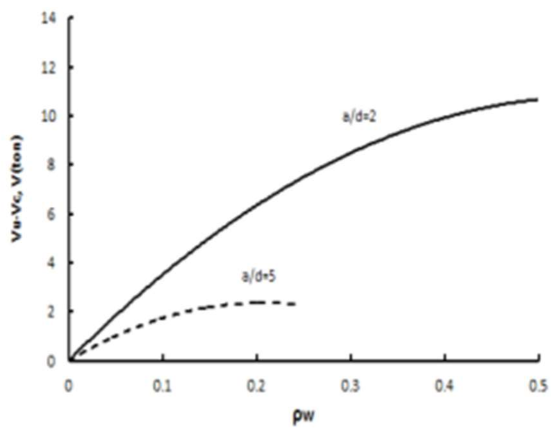

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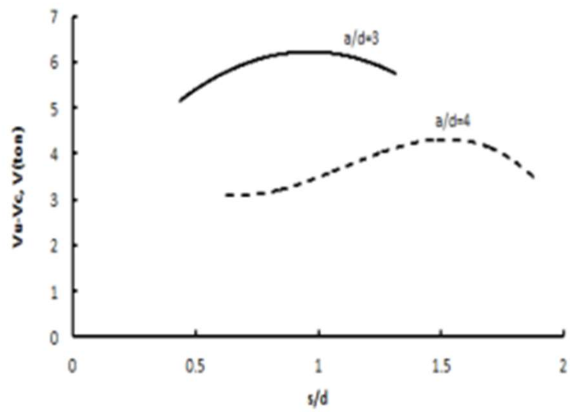

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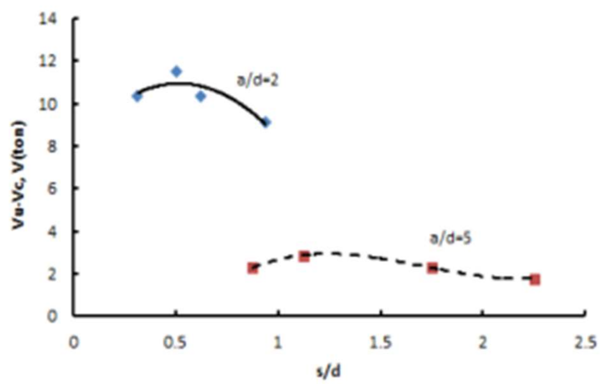

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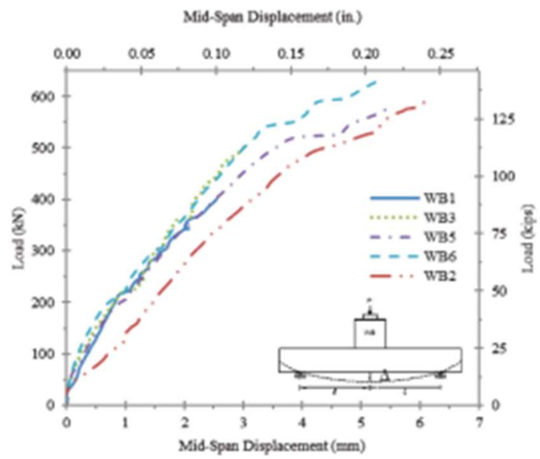
Figure 4. Shear response of Lotfy et al., (2014) [5]: (a) influence of web rebar (a/d = 3 & 4). (b) influence of web rebar (a/d = 2 & 5) (c) effect of s/d (a/d = 3 & 4). (d) effect of s/d (a/d = 2 & 5).

Mohammadyan et al., (2015) [6] carried out an experiment that involved the casting of six RC wide beams that were then connected to internal column joints. Furthermore, the purpose of this contribution is to investigate the role of a number of proposed shear reinforcing of such beams. To perform that goal, the first specimen was constructed without any stirrups (reference), the second with traditional stirrups, the third with independent "bent ups," and the fourth with horizontally "mid depth" bars. The fifth specimen had "bent ups" bars in addition to the typical vertical stirrups. The last specimen is made without stirrups to study the effect of two-thirds of the main reinforcement being inserted into the column joint region.

According to the findings, "bent ups" raised the relevant ultimate shear capacity and improved the ductility behavior seriously, as shown in Figure 5.



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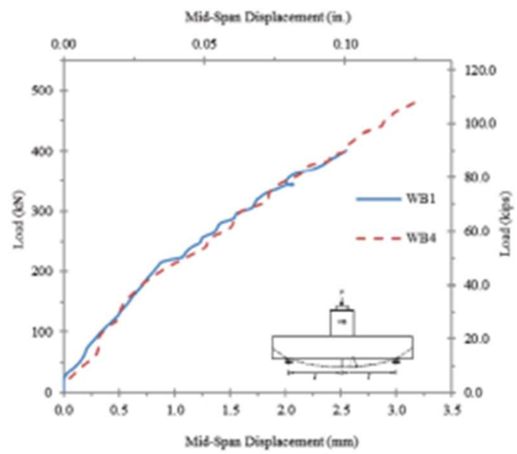
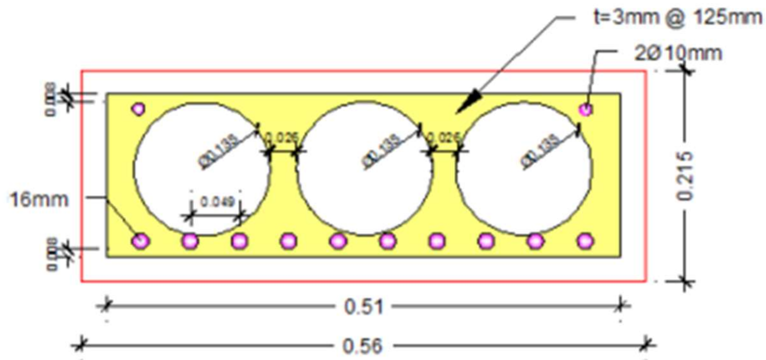


Figure 5. Load-displacement responses of Mohammadyan et al., (2015) [6] specimens

Ibrahim et al., (2016) [2] used an experimental program to suggest a steel plate (commercial automobiles motors gas gate) as a substitute for stirrups reinforcement in RC wide beams, with a variety of plate spacing levels. Five beams were fabricated and tested as part of these research activities. The first specimen, which has the typical stirrups, was made as a reference.

The second was made from a steel plate with 10 mm spacing every 125mm c/c. The third, fourth, and fifth specimens were made from 3 mm steel plates with 120mm, 166mm, and 250mm c/c, respectively. According to the results, the proposed steel plates are an excellent alternative for shear strengthening in wide beams. Furthermore, outer leg strain might be reduced by 175%, while inner leg strain could be reduced by 46 %. Ductility could be increased by 55%, and total weight could be lowered by 2.7 %.

Figure 6. shows the steel plate and stirrups details of such study while Figure 7. shows the load deflection curves.



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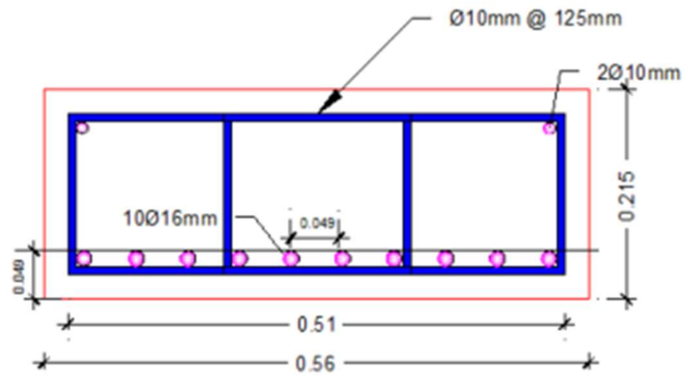

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Figure 6. Steel plate and stirrups details of Ibrahim et al., (2016) [2] : (a) Proposed steel. (b) Stirrups.

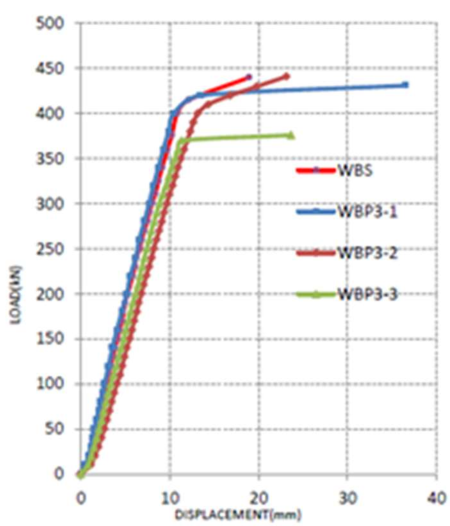
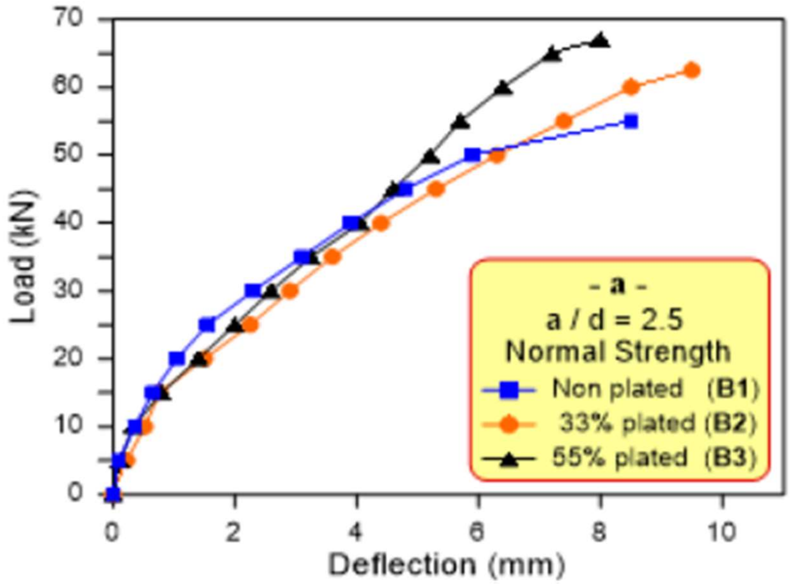


Figure 7. Load deflection response of Ibrahim et al., (2016) [2].

Abbas et al., (2018) [7] carried out an experimental study that involved casting and testing nine RC wide beams that had been modified with "side bonded steel plates" for shear behavior. Concrete strength level (normal and high strength), plating ratio (side covered area to total side area), and (a/d) ratio were the variables used in that contribution.

The inclusion of steel plates improves subsequent initial cracking and ultimate load, and this improvement was increased as a/d increases. According to that study, when the plating ratio is 33 %, ultimate shear strength increases by 8% to 22%, but when the plating ratio is 55 %, it increases by 15% to 23%. Figure views the influence of plating ratio within results regarding such contribution.



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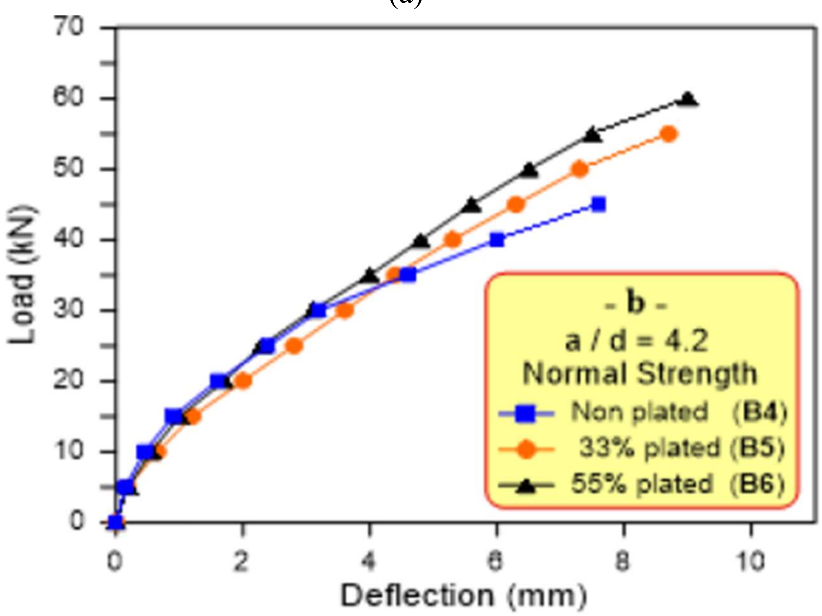

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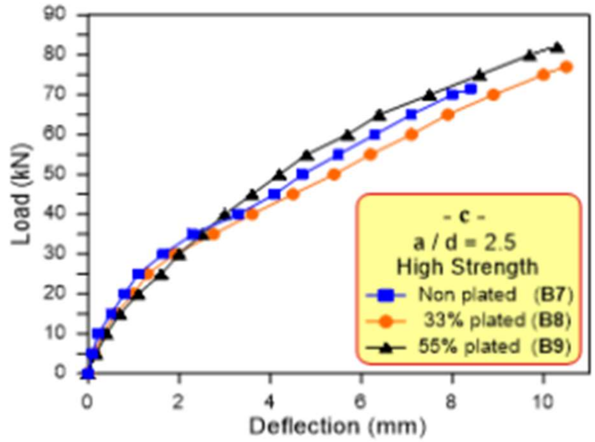

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Figure 8. Platting ratio within the experimental results of Abbas et al., (2018) [7]: (a) a/d = 2.5 “Normal strength”. (b) a/d = 4 “Normal strength”. (c) a/d = 2.5 “High strength”.

Morsy and El-Raki (2018) [8] presented the findings of an experimental program that involved the casting and testing of twelve RC wide beams without stirrups for the purpose of studying shear behavior. The (a/d) ratio (between 1.8 and 2.4), the longitudinal rebar ratio (0.02 to 0.03), the number of end hocked steel fibers (0.75 percent and 1.25 percent), and the applicable compressive strength of concrete were identified as critical components during that experimental program (21 MPa and 51 MPa). Ultimate shear capacity, cracking load, and related ductility were used to depict structural shear behavior in this investigation.

The results of that recent contribution demonstrated that raising the a/d ratio, compressive strength, and the number of steel fibers within the matrix increased ultimate shear capacity and related ductility. During that recent contribution, 0.75 percent of steel fibers were found to have the best shear response.

Abbas and Hassan (2019) [9] performed an experimental program that included the casting and testing of four RC beams in order to assess the effect of carbon fiber polymer CFRP strips for shear strength. All of the evaluated beams had a compressive strength of 30 MPa, with CFRP strips studied in both vertical and inclined modes as variables in the study. In addition, the ultimate shear capacity, first cracking load levels, load – deflection curves, load – strain curves, and the appropriate mode of failure are all characteristics of that study's shear structural response.

The results showed that the ultimate shear capacity was increased by 19.9% and 7.14% for inclined and vertical CFRP alignment respectively.

To investigate certain typical design equations, Khalil et al., (2019) [10] executed an experimental program that included manufacturing and testing of seven RC wide beams. The beam “width over effective depth (b/d) and the column width to “effective depth” (c/d) variables were chosen to fit the data input of these equations. The ultimate shear strength, the cracking load, the load mid - span deflection curves, and the appropriate load strain diagrams were used to quantify the structural shear response.

The results showed that the AASHTO and Euro code predicting equation do not reveal the adequate behavior ultimately as shown in Figure 9.

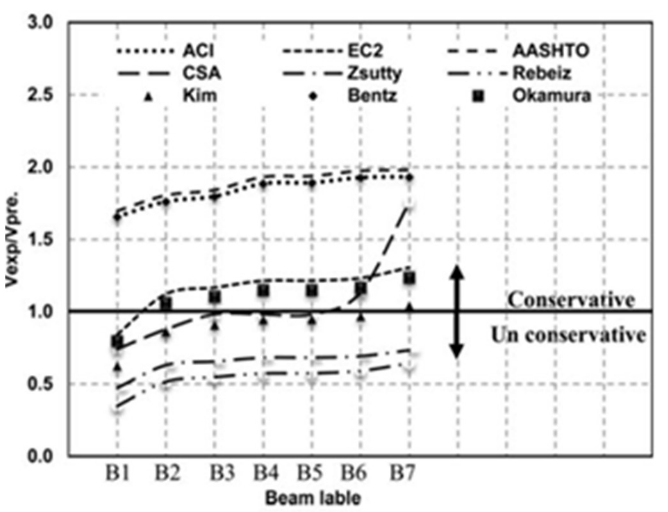
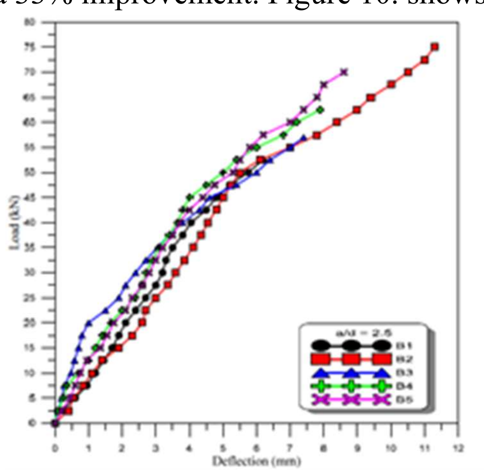


Figure 9. Experimental versus predicted shear force of Khalil et al., (2019) [10]

Abbas (2020) [11] carried out an experimental program that included the fabrication of a hybrid section wide beam for shear behavior. The compressive strength level (a/d) and hybrid section arrangement were the variables in that study. Placing high-strength concrete on top and regular concrete on the bottom, and vice versa, is one such section arrangement. Furthermore, one of the sections was built by separating the hybrid section into three parts, with the top and bottom parts being cast using high-strength concrete and the middle with regular concrete.
It is deduced throughout that research that increasing the (a/d) ratio decreases the relevant first cracking load "especially in high strength concrete" as well as the consequent ultimate loads.
According to the findings of that study, when a wide beam is formed of high-strength concrete, the ultimate shear strength increased by roughly 43%. When conventional concrete is at the top and high strength concrete is at the bottom of the section, the ultimate load capacity may increase by 8.5%, while the three layers indicate a 33% improvement. Figure 10. shows some results of that study.



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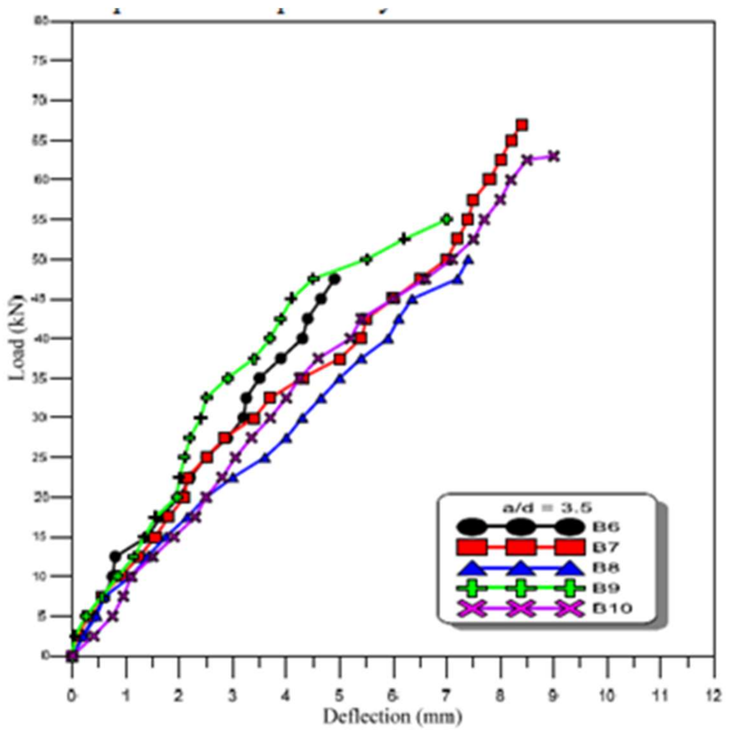

(b)

Figure 10. Experimental results of Abbas, (2020)[11] : (a) a/d =2.5. (b) a/d = 3.5.

Abduljabar, (2021) [12] conducted an experimental program to study effect of steel fibers on shear capacity of reinforced concrete wide beams. such program includes implementing 24 RC beams. Two “shear span to depth” ratios were taken which are “2.5 and 3.5”. Two compressive strengths were studied as “Normal strength concrete” as well as “High strength concrete”. Two kinds of “steel fibers” are used; "End Hocked" as well as the "Staggered" in 0.5% and 1.5% of degree of replacement to the two kinds.

The experimental findings of that study affirmed that the mechanical strength development due to the presence of steel fibers can lead to significant improvement in the related structural behavior and the mode of failure can be changed from “shear” to “flexural”.

During that study, it is reported that “first cracking load” increased in "Normal strength" from 21.95% to 73.73% by adding "End Hocked" and from “12.19% to 45.45%” for "Staggered" while such range were reported as “15.95% to 45.76%” for "End Hocked" and “”7.25% to 28.81%”” for "Staggered" in "High strength". Figure (2-14) shows the load deflection response normal strength specimens having a/d equals to 2.5.

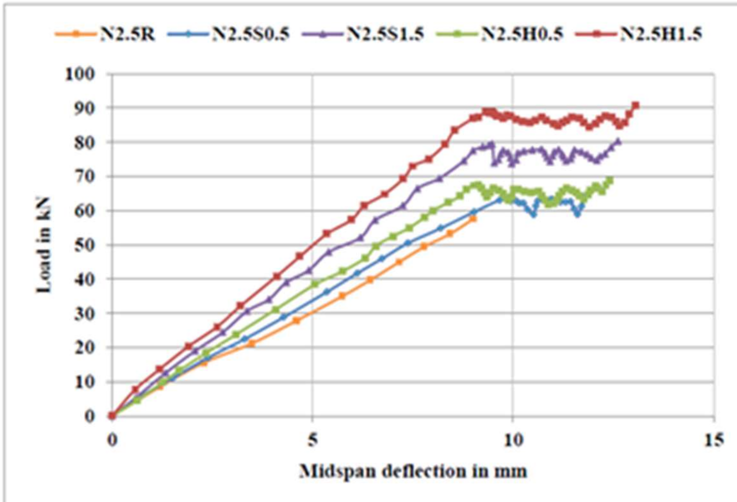

Figure 11. Load deflection response of Abduljabar, H.T., (2021) [12]

4.Conclusions

The Following conclusions can be drawn from this study:

1) The presence of wide beam is very useful in the building systems that can face seismicity.
2) Reinforced concrete wide beams can be considered as simple and cost-effective alternatives which can provide structural depth that is shallower.
3) Warehouses, commercial buildings, and parking lots are the most important applications that can include reinforced concrete wide beams.
4) The reinforced concrete behavior is governed usually by the beam theory with respect to shear and flexural.
5) The structural behavior of reinforced concrete wide beams can characterized by the load deflection curves and the relevant service , ultimate and cracking loads.

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