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أ.م.د. سهاد محمد عبد

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Ministry of Higher Education
and Scientific Research
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College of Engineering

Structural Behavior of Reinforced Concrete Beams with Different Alternatives Techniques for Shear Reinforcement

A Thesis Submitted to the Council of College of Engineering, University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering

By
Isam Saleem Mhaimeed
BSc. Civil Engineering, 2016

Supervised by
Assist. Prof Dr. Suhad M. Abd

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Chapter One

Introduction

1.1 Introduction

The failure in beams can be classified as shear or flexural. The complexity of the shear failure in reinforced concrete beams beside the suddenly occurrence confirms the risk of this type of failure. Thus, most codes necessitate higher factors of safety in comparison with that of the flexural design, since the shear failure is brittle while the flexural is ductile (**Amaireha** et. al, 2019). The shear failure take place in the form of diagonal cracks in the vicinity of the supports. The stirrups are placed in the zone between the support and the loading point in order to enhance the shear strength.

The traditional stirrups are most commonly used as a shear reinforcement, in reinforced concrete building construction, for their simple installation and fabrication. Stirrups are spaced closely at the high shear region. However, the corrosion of the shear steel reinforcement leads to deteriorate the structures performance (**Coronelli** and **Gambarova** 2004; **Val** 2007; **Higgins** and **Farrow** 2006). The corrosion leads to reduce the steel bar cross-sectional area specially, with thin steel stirrups and low concrete cover as compared with the longitudinal reinforcement. Furthermore, the corrosion accompanied by volumetric expansion that have destructive effect on the bond between the steel bars and concrete. The use of fiber reinforced polymer FRP bars came to overcome this problem. Despite that the FRP bars are characterized by the low axial stiffness and higher tensile strain which leads to wider cracks and depression in the neutral axis depth (**El Chabib** and **Nehdi**, 2008). Furthermore, **Shehata**

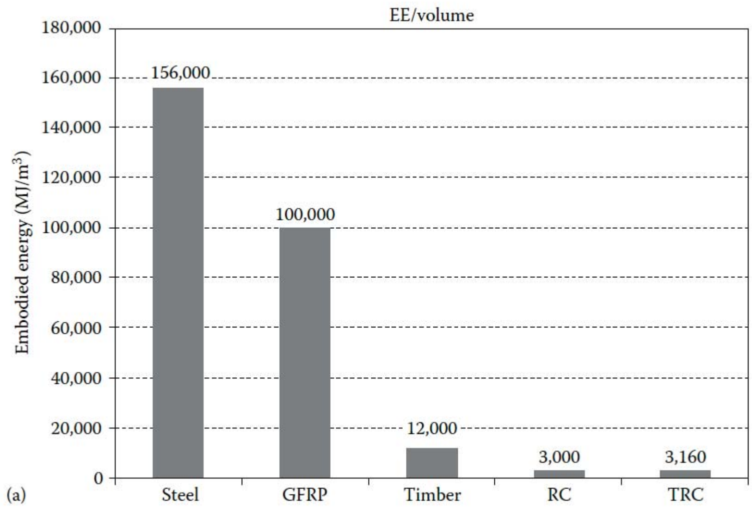
(1998) stated an ideal reduction in the ultimate strength of FRP bars when it used as stirrups. While the bends represents the points at which the failure of FRP stirrups occurs extremely. Therefore, when estimate shear capacity, a reduction factor must be take into account in case of FRP shear reinforcement (**El Chabib** and **Nehdi**, 2008).

In recent years the textile reinforcement is widely researched and used in reinforcing concrete beams, slabs and thin plates. However, the design for bending is completely differ from that of the shear case. Accordingly, the researchers and engineers are yet challenged with an essential issues concerning the carbon reinforced concrete shear design (**Bielak** et al 2019).

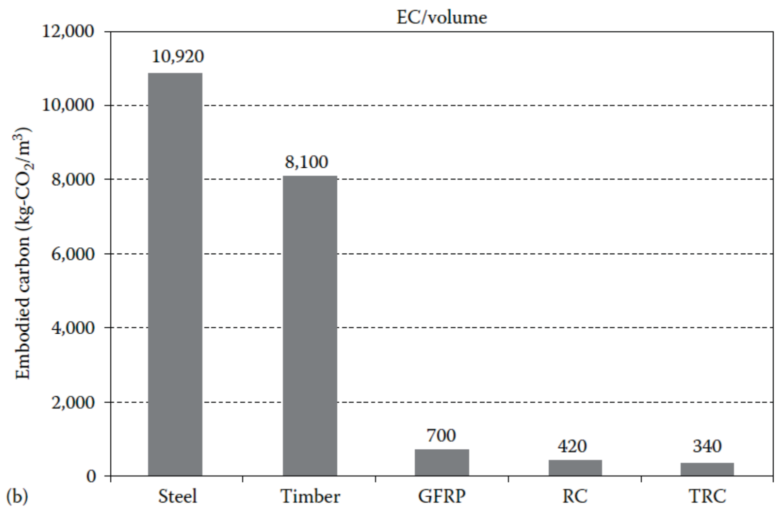
1.2 Sustainability Aspect

The textile reinforcement that embedded in the concrete to compose the TRC is responsible for the excellent characteristics that the last exhibits. Accordingly, the TRC offers more advantages as compared with the other construction materials. However, this comparison is not achieved with the concrete solely, but rather with premium-performance materials like wood and steel, which differentiates by their appropriate mechanical performance, as quantified in terms of ductility, tensile strength and strength/weight ratio (**Peled** et al 2017). The CO_2 emission and the energy considered a practical indicator about the sustainability of the materials. Figure (1-1(a and b)) shows the CO_2 emission in (kg-CO_2/kg) units and the energy in (MJ/kg) units per unit volume for the ordinary construction materials. As can be noticed that the TRC exhibits similar values with the conventional reinforced concrete, despite that the former is reinforced by more than twice volume of reinforcement from that of the latter, however the last two materials showed less values of CO_2 emission and embodied energy as compared with the other construction material (**Peled** et al 2017).

The use of textile reinforcement as shear stirrups instead of the conventional steel reinforcement would reduce the CO_2 emission and minimize the embodied energy.



(a) The energy of CO_2



(b) The CO_2 emission

Figure (1-1(a and b)) shows the CO_2 emission in (kg-CO_2/kg) units and the energy in (MJ/kg) units per unit volume.(Peled et al 2017)

1.3 Research Significance

The high tensile strength of the carbon textile reinforcement as compared with the steel reinforcement, low weight to strength ratio and resistance to corrosion promotes the use of this type of reinforcement as shear stirrups instead of the steel reinforcement. Furthermore, the sustainability aspect entails usage of materials with characteristics such as that the textiles possess.

1.4 Statement of problem

The steel reinforcement exposure to rust and corrosion over time and its resistance to harsh conditions in terms of moisture, acids and chemicals, in addition to the need for a concrete cover to protect the steel, which means an increase in the cost as well as pollution associated with the manufacture of steel and the release of CO_2 emission .

1.5 Aim and objectives of the study

The main aim of this study is the use of suggested alternatives reinforcement techniques as shear reinforcement stirrups instead of the conventional steel stirrups, the specific objectives that are accounted in this study are:

- Investigating using different shear reinforcing techniques for reinforced concrete beams, the proposed techniques are: Carbon textile yarns and Flamingo steel reinforcement.
- Investigating to use material less weight and resistant to rust and harsh weather conditions.

- Compare the structural behavior for the proposed techniques with beams without shear reinforcement and with the traditional method for shear reinforcement using stirrups and,

- Determine the most effective method for improving or enhancing the shear capacity.

1.6 Scope of the study

The experimental program of this study consists of casting, testing of teen beams. The obtained results discussed in terms of ultimate load, load-deflection relationship, load- concrete compressive strength and crack pattern and mode of failure. The limitations related to the aspects are summarized as follows:

- Textile type is limited to carbon only.
- The type of concrete is constant in the field of research.

1.7 Layout of the study

- Chapter one is a general introduction to shear failure in beams and the possibility of using the textiles as a shear reinforcement in the beams instead of other types of reinforcement. It also describes the aims of the study.
- Chapter Two presents the literature review of the previous work concerning the shear techniques in beams.
- Chapter three explains the experimental work and the properties of the
- Materials used.
- Chapter four presents the experimental results of the whole tests that took

  Place in this study and their discussion with details.
- Chapter five represents the conclusions obtained from this study and Recommendations for future studies.

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ABSTRACT

The shear failure is unlike flexural failure since it occurs suddenly with clear brittleness. Therefore, the traditional steel stirrups that characterized by high ductility are used as a shear reinforcement. It is well known that steel reinforcement could undergo corrosion under specific circumstances, which leads to durability problems and deteriorate the concrete structures, hence the demand for the non-corrosive material become necessary.

In this study, experimental investigation has been carried out in order to study the shear behavior of reinforced concrete beams using different reinforcing materials such as; the traditional steel stirrups and textile carbon yarns, in addition to develop new shear reinforcement technique which is the flamingo technique. Twelve beams with dimensions of (200mm×300mm×1500mm) were casted, cured and tested under two point bending. Two beams were with and without shear reinforcement adopted as control beams, six beams were with textile carbon yarns with different length of overlap (100%, 60% and 30%) from the effective depth, different angle of inclination (45°), different spacing and different methods to improve the bond between the carbon yarns and the concrete using the short steel fibers. The remaining four beams were with flamingo steel reinforcing technique with different lengths and inclination for both upper and lower free ends.

The experimental results revealed that increasing the length of the overlap for the textile yarn stirrups by 100% increased the ultimate load 24.5% and showed reduction in the deflection as compared with that of steel stirrups.

Moreover, decreasing the spacing between the yarn stirrups to 90 mm without increasing the area of shear reinforcement leads to increase the ultimate load by 26% while the deflection was reduced by 30.1% as compared with that of traditional steel stirrups. Furthermore, the inclination of the textile yarn stirrups by 45° exhibited an excellent increase in the ultimate load by 55% while the deflection reduced by 3% compared to that of steel stirrups. The impregnation in the mortar with the steel fiber lead to a slight increase in the ultimate load by 3% while deflection was reduced by 13.63%.The flamingo technique showed excellent results in terms of load-deflection behavior, stiffness, cracking behavior, less crack width and shear ductility as compared with the traditional steel stirrups. The beam **F -60-80-30°** of flamingo reinforcement, yield higher load carrying capacity by about 56%, increasing in deflection by about 40.25% and in crack width by about 7.7% than the reference beam. In shear ductility that was an Improvement in beam F -45-75-40 by about 52% than the reference beam.