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AN OVERVIEW ON DIFFERENT REINFORCING BARS FROM MANUFACTURING TO STRENGTHENING ELEMENT

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ABSTRACT

The reinforcing bars have been known to increment strength in the composite materials. The development in variable materials and their intended use in either horizontal or vertical members diversify the importance of the reinforcing bars. The most commonly used material for reinforcing bars is steel which is vulnerable to corrosion and is expensive. Other materials are still limited in competing for steel. The shape and geometry of the rebars also have much significance. Studies have been carried out for improving the properties of the composites through better performance rebars. Also enduring the performance in earthquake resisting housing the development of rebars has resulted in safer and extreme performance variants of the reinforcing bars. The construction industry out of all this enormous use of rebars from different materials is requiring sustainable solutions and low-cost solutions. This study intends to overview the materials available for reinforcing bars. Further exploration is required to provide a substitute for steel reinforcing bars through recycling of waste plastic or other means.

Keywords: *Rebar, steel bars, stiffeners*

1. INTRODUCTION

The reinforcing bars are a result of long history associated with building and construction. In literature the development of patent for RC goes back in 1867. The idea was related to the profitability of the manufacturing flower pots and has regarded less to the actual structural significance. The pioneer Joseph Monier although had in mind to develop durable flower pots with use of steel and cement (Marcos et al., 2018). The reinforcement being used in the market today provides a variety of properties such as high strength, ductility, crack arrest, energy absorption and others. Over a period of time the use of rebar is improving with well formulated codes and standards.

The different types of rebar are available and research is being progressively matured to control the failure pattern of concrete through rebar. The rebar or reinforcing bars are available of different materials the manufactured rebar contains a special set of dimensions and surface structures and other physical and chemical compositions. The coir fibre has also been used in research as to control the tensile loads of a structural system under dynamic loads (Ali & Chouw, 2008). The results are found satisfactory and are a cheaper alternative than steel. The research program is focusing in using alternative sustainable materials such as recycled waste plastic to produce rebar (Das & Ali, 2021a). The construction industry uses the rebar to envelop the tensile area and in mortar free construction the rebar are used as stiffener to control the upward forces (Ali et al., 2013). These studies were further extended with the idea of another research that the ropes can counter the uplift force caused due to seismic action (Ali, 2016).

The purpose of this study is to overview different geometries and different materials for rebar for intended replacement of steel from recycled waste plastic rebar. The option to recycle waste plastic is currently being demanded all over the World as only 9% of the disposal is being recycled (Geyer et al., 2017). The construction industry can employ waste plastic as a plausible material which is not only cheaper but is resistant to corrosion as for low strength use.

2. SURFACE GEOMETRY OF REINFORCING BARS

The reinforcing bars have a set of surface properties, geometric properties, chemical manufacturing properties, chemical reactivity properties etc. These are well explored in literature specially for steel. Surface geometries include the provision of ribs for a single diameter of reinforcement. The properties roam around to one single idea that either the bond between bars and the concrete is of sufficient strength or otherwise (Leramo et al., 2018).

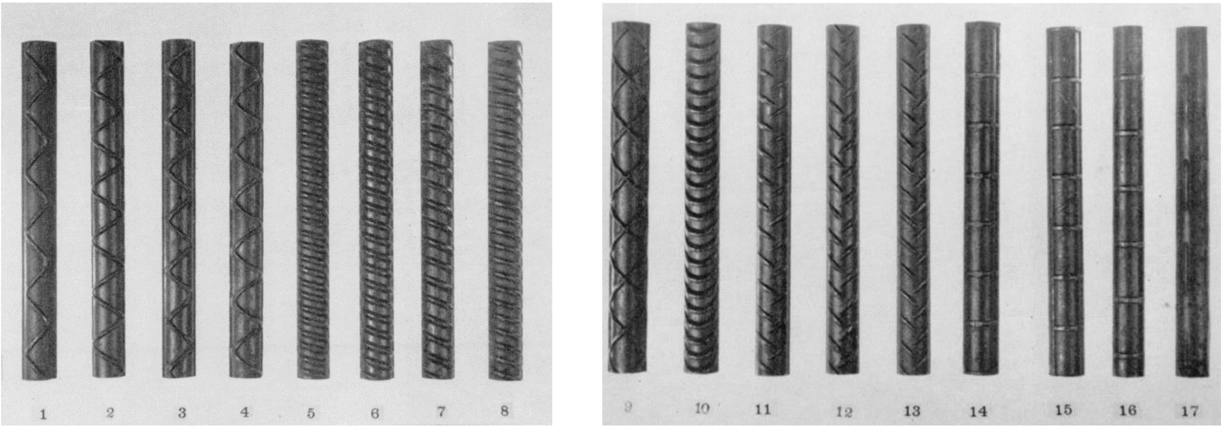

Figure 1: Different ribbed reinforcement tested for strength (Clark, 1946)

The mechanical interlocking is greatly improved by improving the surfaced ribs. Behaviour of different ribs were studied in a research of early days and the result shows significant variations due to shape and orientations of ribs. The results of a few ribs were found better out of 17 available options (Clark, 1946). In providing a response to cyclic loading the orientation of ribs is very important (Darwin & Graham, 1993). The researchers conclude that the ribs inclination control the slippage and pull out failure. The Lutz and Gergely in 1967, advocated that the inclination should be between 300 to 400 (Leramo et al., 2018). In another study the inclination angle was recorded to be 48.5 (Skorobogatov & Edwards, 1979). The basic ideology of the ribs is to transfer the stress into the reinforcing bars without slippage. The thickness and cross sectional area is however dependent upon the overall dimension of the structure. Figure 1 shows several surface geometries of reinforcing steel bars. The surface geometry is so significant that each shape behaves differently in reinforced concrete. These surface geometries were randomly numbered and tested in load transmission and pull out in reinforced concrete. The conclusion drawn was that the shapes 8,9,6,3,4, and 5 were the most effective. (Clark, 1946).

The naturally occurring reinforcing bars are organic and their geometry is not uniform. The pattern of surface does not have the “perfect bond” in which all the forces of concrete are transferred to its bars. Bamboo is one of the used rebar found in the literature to be used in the concrete (Sevalia et al., 2013). These are not mouldable to any certain surface and are brittle in nature. Mortar free construction uses stiffeners or vertical members to hold the system in dynamic loads. In a study coir fibres were used as tensile ropes which was designed to keep the block intact and the mechanism of mortar free construction was found efficient in energy dissipation (Ali & Chouw, 2008).

3. REINFORCING BARS OF DIFFERENT MATERIALS

Due to steel being expensive and prone to chloride attack different materials have been developed to replace steel as reinforcing bars (Adam et al., 2015). Fibre reinforced polymers are another variant material which has lower electromagnetic interference as compared to steel, lighter in weight and good against corrosion. The only problem recorded is that it shows different behaviour in different direction being anisotropic. The dowel action is also tested to be unsatisfactory. In bend test the FRP bars were found to be brittle. A different mechanism exists to use FRP bars in specific areas (Mousavi & Esfahani, 2012).

The GFRP rebars have also been recorded to be used recently. The use was with jute fibre concrete and different samples were tested for impact loadings (Patil & Manjunatha, 2020) In other researches the use of bamboo is also being proposed for flexural members, having strength of almost 25% to that of steel. In addition to this an idea was developed that the under developed regions can use bamboo for low cost construction (Qaiser et al., 2020)(Al-Fasih et al., 2021). The bamboo is organic and have other issues except for the fact that the limited and properly designed use can give a solution as an alternate to the steel (Archila et al., 2018).

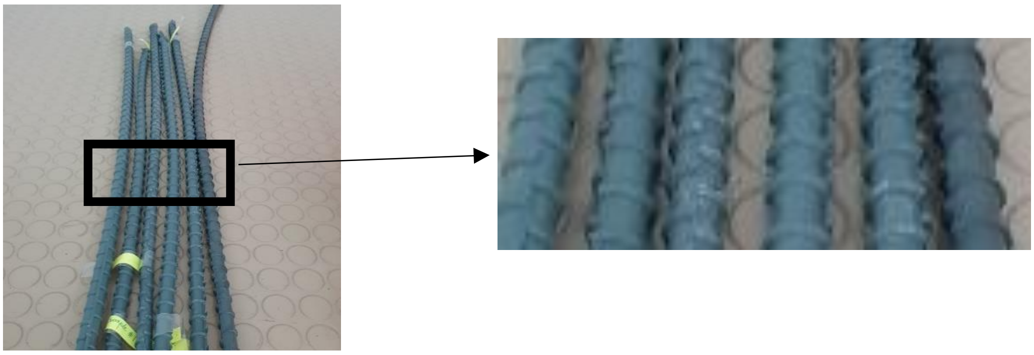

Figure 2: Waste Plastic recycled rebar produced from extrusion (Das & Ali, 2021b)

Thermo-mechanically treated TMT rebars are also being developed which have high efficiency (Sk et al., 2016). The tensile stress absorption capacity remains the same for a certain set of material as the stress in a function of force per unit application area. The material suitable for rebar are ductile as it provides sufficient energy absorption during seismic loads and before failure giving time prior to failure. The brittle rebar on the other hand provide higher strength but after failure the member collapses suddenly making the failure global.

The natural mineral basalt found in volcanic rock also has been employed to produce rebar. The BFRP is manufactured with the same process of as GFRP and the same is good thermal, chemical stability and better alkali resistance (Hadi et al., 2021). The coir fibre ropes were tested in a research in RC columns and the results were exemplary in terms of dynamic responses especially before cracking (Ali, 2014). Figure 2 shows the recently developed of waste plastic recycled rebar produced through extrusion. Under this research program waste plastic rebar were tested for energy absorption capabilities which showed that plastic can be used as a potential material for rebar for low cost construction (Das & Ali, 2021b). This area requires exploration for improving the product properties prior to use in construction.

4. USE OF REINFORCING BARS WITH STRUCTURAL LIMITATIONS

The rebar controls the crack development and crack propagation; the mix is complemented when short discrete fibres are placed in the concrete. The overall system having rebars intends to provide better resistance to spalling, thermal cracking and other problems which damage the concrete in long term or for abrupt failure (Al-Khafaji et al., 2021).

Table 1: Comparison of codes for Reinforcing bar (Gabriel, 2003)(EN 10080, 2005)(Standard, 2004)

Item	**ASTM A615 (Standard, 2004)**	**BS 4449-2005 (EN 10080, 2005)**	**ISO 6935-2:2007 (Gabriel, 2003)**

Scope	Plain and deformed Bars (Carbon steel).	Deformed Bars	Deformed Bars (ten ribbed)
Manufacture	Manufacturing is by the use of electric furnace, open hearth or basic oxygen	As per the Manufacturer's discretion	As per the Manufacturer's discretion
Chemical composition	Should not exceed the following chemical composition Phosphorous 0.06%	Should not exceed the following chemical composition Carbon 0.22 % Sulphur 0.05% Phosphorous 0.05 % Nitrogen 0.012 % Copper 0.8 % Carbon equivalent 0.5% Calculated through a formula	Should not exceed the following chemical composition Carbon 0.22 % Sulphur 0.05% Phosphorous 0.05 % Nitrogen 0.012 % Copper 0.8 % Carbon equivalent 0.5% Calculated through a formula
Tensile Requirement and grades	Covered grades: Grade 40 (280 MPa) Grade 60 (420 MPa) Grade 75 (520 MPa) For 8 in (200mm) gauge length different values of elongation ranging from 6% to 12% is specified in Table 2 for different sizes and grades. With permissible strain variation	Covered grades: Grade 72.5 (500 MPa) Details are given in Table 4 for tensile properties	Covered grades: Grade 43 to Grade 72 (300 to 500 MPa) Details are given in Table 6 for tensile properties
Bending requirement	Bend angle at room temperature is 180°.	Up to 90° bend, and bend back to 20°.	Bend angle defined is 160° to 180°.
Variation in weight (mass)	6% variation of weight	±4.5% to ±6% on nominal diameter 8mm) and less than 8mm respectively.	±4% to ±8%, as per diameter of the bar

Different standards provide different limitations. Table 1 provides a comparison of codes presented for steel reinforcing bars reinforcing bars highlighting the properties of the commercially available steel bars (Manzoor & Ahmad, 2013). The use of newer materials being evaluated in research require new codes explicitly for practice and implementation.

Since the development of the rebar the idea was to strengthen the concrete in tensile load carrying capacity. As the concrete is weak in tension and does not carry serviceable loads in tensile therefore reinforcing bars were structurally popular. The strengthening was due to the ribs on the surface of the bars which provide resistance towards slippage and also transfer the external load to the rebar. the increase was efficiently utilized in the research and even compression members are being reinforced with confinement provided from stirrups. In shear walls the lateral and in plane forces are catered by the reinforcing steel (Nguyen et al., 2020).

The literature also provides the use of steel rebar as stiffeners in mortar free construction. The assembly of the mortar free construction uses vertical ties which are fixed from the top and bottom of the wall. The blocks in the system are free to move and dissipate energy. The shape of the block is so designed that after seismic activity the block moves and slides back to its original position (Ali, 2018). The stiffeners when developed from a costly material such as steel increases the overall cost of the construction.

5. CONCLUSIONS

The reinforcing bars presently available in the market are usually made up of steel and is expensive. Therefore, there is a need to explore different materials to produce rebar. Following conclusions can be drawn

- Different variety of geometries surface as well sizes, diameter has been used which changes the bond behaviour and transfer of loads in composites having rebar.
- Every material has its own unique property to impart to the rebars. Steel being strong and ductile but is corrosive. The organic rebar does not have any patent shape and are usually brittle. The area which is grey is waste plastic.
- The rebar primarily strengthens the concrete under tensile loads and improves compressive strength. In mortar free construction the primary function of rebar is to provide tensile stiffness. This requirement is being met by costly steel efficiently, however, option for less costly material can be opted to replace steel.

Further studies are required to develop rebar from sustainable materials such as recycled waste plastic. The mechanical properties and properties under cyclic loads needs to be examined for waste plastic bars for their intended use in the building sector.

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