

Recycling of Steel Bars from Demolished Structures

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Abstract

Strengthening steel bars are usually gathered and sent to scrap sites, where they are melted, and made again into a new reinforcement bar. In Jordan, the demolition of old buildings is creating a growing industry together. The entrepreneurs collect the used steel reinforcement bars (rebars), and manually strain them and then market them at half the price of the new steel bars. If the use of these bars is appropriate, more benefits will be achieved, such as saving energy required to manufacture steel bars, and reducing CO₂ emissions. The aim of this paper is to analyze how well the stressed steel bars are appropriate for use with the new concrete in terms of bonding strength.

Keywords: Recycled reinforcing steel bars, bond strength, tensile strength

INTRODUCTION

The purpose of this paper is to examine how well the stressed steel bars are suitable for bonding strength applications with new concrete. The use of building products and their recycling reduces waste, saves basic resources and energy and related emissions of greenhouse gasses. Steel has a high intrinsic value and promotes an effective scrap collection; however, the focus is often placed on the recyclability of this metal when addressing environmental effects of the steel production cycles. While this is an advantage particularly for saving energy and reducing negative effects on the environment, another reduced impact option exists: material reuse.

In their analysis Fujita & Iwata (2008) noticed that steel structures were reused to reduce the environmental impact: the necessary measures needed to set up the system. They use the recycled steel bars to produce a cyclical process of reuse by design, processing, development, repair, demolition and storage. Fujita & Iwata (2008) developed a vein industry that promotes the manufacturing, recycling and reusability of arterial products in comparison with the arterial sector, which is responsible for produced and distributing newly produced members.

The loss of steel resources can lead, from an environmental perspective, to the degradation of its climate; hence the use of recycled steel bars can contribute to an atmosphere that is greener. The following are presented: degradation of the natural habitats of many species (Winfield and Taylor 2004), some of the environmental effects of mining and using

recycled steel bars, increased greenhouse gas emissions due to mining, treatment and transportation energy consumption. As the transport gap from mining and processing plants to building sites increases; the greenhouse gas emissions also increases.

Paz et al. (2014) reported that, by replacing different percentages of the natural coarse aggregate with the recycled coarse aggregate, the bonds behavior of recycled aggregate concrete allowed variations between traditional concrete bond strength and recycled concrete bond strength to be identified depending on the substitution level, and that the stress bonding was observed.

With experimental results, a revised definition can be created to estimate a maximum bonding stress (bond strength), keeping the condition and compressive strength of the steel bars into account. This provides an interaction benefit close to that of traditional concrete to the theoretical prediction ratio. The collection of used bars is a thriving enterprise in Jordan when old structures are demolished as seen in figure 1.



Figure 1. A location for demolition in Amman

The collected steel bars are transported to the workshop in the Rageeb region of industry. All of them were now tangled and baked, as shown in Figure 2 and 3.



Figure 2. Set of demolition site steel bars



Figure 3. Recycled steel bars arrive in the industrial area of Rageeb

The workers bend these bars by hand to their almost original straight shape using a bending table, also have the sliding bar diameter and are manually sorted by the yield force (grade 40 or grade 60), depending on the bending experience of the bar and the stiffness he feels during bending, as shown in Figures 4 and 5.



Figure 4. The workbench used to stretch the steel bars manually



Figure 5. Sorting of steel bars

A survey conducted in year 2000 and replicated in 2012 with demolition contractors reveals that the reused steel bars in superstructures constitute zero percent of the total waste whereas that is approximately two percent of the rebars waste in structures and foundations. Studies in 2016 investigating the mechanical features of bent bars as a factor to limit their reuse, steel bars with different diameters have been bent and their tensile strength tests have been carried out after each bending.

The findings have shown that the effect of a rebar's single bend is not apparent, while the tensile strength and elongation value are altered. When strength decreases and the elongation value is major, for bars #10 mm and 12 mm the third curve is critical (with bars #8 mm the fourth bend is critical).

In particular we think the reuse levels listed will increase for residential buildings of one or two floors in damaged areas, since the second study shows that tensile strength is not greatly impacted due to bending particularly in the case of small diameters and any reduction in bond strength will be balanced by an increasing construction length. An investigational program has been carried out to analyze if the bond strength of recycled steel bars is impacted.

EXPERIMENTAL SETUP AND RESULTS



A variety of pullout tests were conducted on both new and used reinforcement bars to determine the bond strength of the used bars. The first group consisted of standard concrete strength, and the second group of concrete high strength. In the center of a recently cast 300 mm concrete ring, new and used reinforcement bars were mounted as shown in Fig. 6, cured to the full strength of the concrete, and then tested. Steel bar diameters of 12 mm, 14 mm and 16 mm were used for the research. Three samples were prepared and tested for each diameter. Another with a maximum power of 20-MPa and the other 35-MPa was planned for two concrete construction mixtures. The concrete reached stated strengths were verified by cylinder tested at 28 days.



Figure 6. Cylinder in its center with a steel bar undergoing pull-out test

Table 1 and Table 2, respectively for concrete 20-MPa and Table 3 and Table 4 respectively for 35-MPa concrete strength, are shown accordance with BS 5080: part 1: 1993. Table 2 shows new steel bars pullout test for 35-MPa concrete strength

Table 1. New steel and concrete performance pull-out test 20-MPa

Bar diameter (mm)	Average failure load (Ton)	Failure mode	Picture
12	6.8	The steel bar pulled out from the concrete	
14	6.04	The concrete cylinder segmented before steel bar pullout	



Bar diameter (mm)	Average failure load (Ton)	Failure mode	Picture
12	6.42	The steel bar pulled out from the concrete	
14	6.04	The concrete cylinder segmented before steel bar pullout	

Table 3. New steel bars pullout test and 35-MPa concrete strength



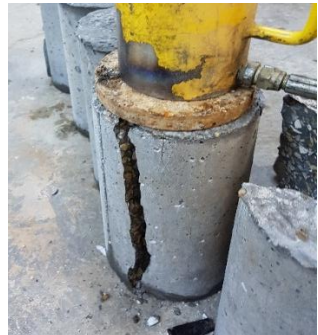



Bar diameter (mm)	Average failure load (Ton)	Failure mode	Picture
12	6.	The steel bar pulled out from the concrete	
14	8.2	The concrete cylinder segmented before steel bar pullout	
16	9.	The concrete cylinder segmented before steel bar pullout	

Table 4. Test pullout for used steel bars of 35-MPa concrete.

Bar diameter (mm)	Average failure load (Ton)	Failure mode	Picture
12	6.	The steel bar pulled out from the concrete	
14	6.8	The concrete cylinder segmented before steel bar pullout	
16	9.	The concrete cylinder segmented before steel bar pullout	

DISCUSSION AND CONCLUSIONS

For used as well as new steel bars and for both the concrete strength of 20-MPa and 35-MPa we see that the 12-mm steel bar pulled the concrete cylinder at the same strength. The bonding strength depending on the diameter of the steel bar is thus effective in bond failure and the used steel has the same bonding strength.

We find that, before achieving full length of development for both new and used steel bars in concrete strengths of 20-MPa and 35-MPa, the concrete around the steel bars with diameters of 14 and 16 mm is separated. In the production of bond strength, the concrete strength and cover are thus more essential.

All new and used steel remained inside the concrete, after the fragmented cylinder was checked, as shown in the figure. 7 and Fig. 8; e.g. bond strength depends instead of physical adhesion between the concrete and steel on the deformations of the steel bars. This implies that it should be clean of any

old concrete Derbies to be suitable as building reinforcement steel.



Figure 7. Used after segmentation deformed steel bar indentations



Figure 8. Fresh indentations of deformed steel bar after division

Ultimately, we conclude that used recycled steel bars can be used as construction material with any kind of bonding strength concrete in a safe manner, as both new and used bond strengths were almost standardized.

REFERENCES

- [1] Bribián, Ignacio Zabalza, Antonio Valero Capilla, and Alfonso Aranda Usón. "Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential." *Building and Environment* 46.5 (2011): 1133-1140.
- [2] Sansom, M., and J. Meijer. "Life-cycle assessment (LCA) for steel construction." *EUR* 20570 (2002): 1-160.
- [3] Domski, Jacek, Jacek Katzer, and Mateusz Zakrzewski. "Mechanical characteristics of used bent rebars as a factor limiting their reuse." The 9th International Concrete Conference 2016, Dundee, July 2016.
- [4] Blengini, Gian Andrea, and Tiziana Di Carlo. "The changing role of life cycle phases, subsystems and materials in the LCA of low energy buildings." *Energy and buildings* 42.6 (2010): 869-880.
- [5] Tam, Vivian WY, and C. M. Tam. "Evaluations of existing waste recycling methods: a Hong Kong study." *Building and Environment* 41.12 (2006): 1649-1660.
- [6] M. Fujita & M. Iwata (2008) Reuse system of building steel structures, *Structure and Infrastructure Engineering*, 4:3, 207-220, DOI: 10.1080/15732470600720351.
- [7] Winfield, M.S., Taylor, A. (2005). Replacing the Load: The Need for an Aggregates
- [8] Conservation Strategy for Ontario, Report Published by Pembina Institute for Appropriate Development, ISBN 0-921719-71-x.
- [9] Seara-Paz, S., González-Fonteboia, B., Eiras-López, J. et al. *Mater Struct* (2014) 47: 323. <https://doi.org/10.1617/s11527-013-0063-z>