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Assessment of Using Wastage Steel as Welded Reinforcement

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***Abstract*—**This work is carried out to evaluate the possibility of using to-be-wasted steel as reinforcement after welding together pieces of reinforcing steel bars, left over during construction activities. Tests were performed on a total of nine samples. These were made by welding pieces of reinforcing steel bars purchased from the local scrap steel market. The samples were tested in uniaxial tension using a universal testing machine (UTM). It was found that the failure of the welded bars is governed by the thickness of the weld. It is concluded that suitable design of the weld is essential for achieving the desired level of ductility/elongation of these bars, if they are to be used as conventional reinforcement in reinforced concrete members.

***Keywords*—**Ductility/elongation, low cost housing, reinforced concrete, welding, welded reinforcement, wastage steel.

I. Introduction

THE Naya Pakistan Housing Project (NPHP) is to cope with the shortage of around 10 million houses in the country. Under the project, five million housing units would be built. The features of NPHP also include reducing construction cost by standardizing design and specifications. Research and development efforts are being carried out to reduce project cost by (1) standardizing design and specifications, (2) employing advance and smart structural materials, (3) minimization, reuse and recycling of construction wastes.

Reinforcing steel is an essential component of reinforced concrete construction waste and it has a greater unit cost compared to aggregate and concrete. In some scenarios, reinforcement bars in maintenance process fall short of length and in such cases its optimum to weld these joints [1] and this welding failure in bar lap joint has been resulted in many structural failures in recent past [2]. To use reinforcing steel in an efficient manner, a way can be to adopt a zero/minimum reinforcing steel wastage construction practice. To cut down steel waste, one way among other options can be to explore the possibility of utilizing cutting pieces of reinforcing bars as usual reinforcement using some weld [3] which are otherwise counted in construction waste.

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II. Literature Review

Welded splices of reinforcing bars are highly recommended for many of the concrete structures as suggested by [4]. Previous studies carried out in this area highlighted and evaluated several aspects of this subject area; ranging from production and certification processes [5] to performance of scrap steel [6] and welded deformed reinforcing bars [7] at failure levels. Reference [8] has studied the effectiveness of welding for the repair works of concrete structures. Findings of these studies provide enough evidence for optimism regarding use of welded left-over pieces of reinforcing steel as reinforcement in reinforced concrete members on the condition that the highlighted problems are provided for.

III. Experimental Setup

For steel structure joints, three types of welded connections are designed all over the world. These welded connections are termed as under-matched, matched and over-matched weld joints. In Pakistan, steel structures are not much common in practice except for warehouses and transportation service terminals. Therefore, for residential houses, welding is only done to repair and maintenance purpose and for these, most common welding is under-matched weld joint. In some cases, matched joint condition for steel weld is also observed but it is not in common practice to have over-matched welded joints in Pakistan. In a view point of all these conditions and Naya Pakistan Housing Project, Government of Pakistan is intended to construct low cost housing projects for peoples with lower income. Keeping in mind all this, the idea of using waste as a construction material accelerates rapidly in academic and industrial sector of Pakistan. More than hundred researchers, in recent past, have conducted studies on recycled aggregates and low cost construction materials. Now, it has been observed that a number of steel bar slices are going to be wasted during a construction project and these slices are no more of use for any construction. Here, these slices are tested and analyzed as recycled steel bars and these bars are made using wasted slices and welding them into a single reinforcing bar. For this a matched condition welding joints are utilized and the description of specimen and test procedures are described below.

A. Specimens

Overall, nine specimens were tested in uniaxial tension in order to observe the manner of failure of the bars. Each specimen was made by joining two pieces of reinforcing bars through Shielded-Metal-Arc-Welding (SMAW). For SMAW, Arc length maintained by human operator is one of the most important characteristics. Too small arc may result in a poor penetration [9]. These bars were purchased from local scrap-steel market. As per the common construction practice in Pakistan, 3/8” and 4/8” bars are the most common steel reinforcement used for domestic construction hence the specimen for this analyses are made from these bar sizes. Eight specimens were made using 3/8-inch diameter bars and remaining was made using 4/8-inch diameter bars. The length of prepared specimens is 26 inches (2.17 ft) as shown in Fig. 1. All the slices are taken from 60 ksi steel as this is the most widely used bars in the Pakistan construction industry. ASTM standards were utilized in making the sample sizes and its preparation process.

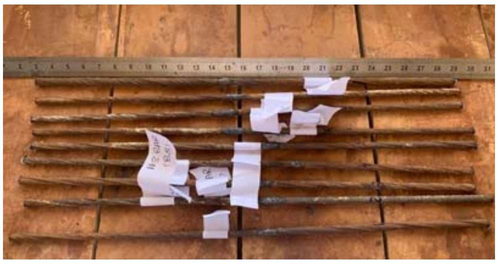


Fig. 1 Prepared Samples

B. Welding

Reference [10] has suggested and assured some basic guidelines and requirements for every type of splices including lap, mechanical and weld splices for steel bars. The type of welded joint used is a butt (head-to-head) joint and the diameter/thickness of weld is kept equal to diameter of the bar except for specimen #1 and #5 (as shown in Fig. 2) where it is purposely kept slightly greater than the bar diameter. Reference [11] found the butt joints as very fine connection with high ductility for symmetrical loading cases. The electrode used for welding (shown in Fig. 3) is of 60 ksi strength, making the matched welding condition. Method of welding is not as per any standard and reliance is made on skills of local welders. This is decided to get an idea about the quality of prevalent welding techniques because most of welding technicians are not certified by any engineering regulatory body.

TABLE I
YIELD AND ULTIMATE LOADS ACHIEVED

Sample No.	Bar Dia. (Inch)	Unit Weight (Kg/m)	Yield load (lbs)	Ultimate load (lbs)
1	3/8	0.5461	7681	10242
2	3/8	0.6063	5972	7962
3	3/8	0.6321	7098	9464
4	3/8	0.5936	7658	10210
5	3/8	0.65	8595	11460
6	3/8	0.5958	7159	9545
7	3/8	0.5688	6771	9028
8	3/8	0.5682	7024	9365
9	½	0.915	9340	12454

A machine used for tensile test, preparation of samples, testing setup, and tested samples are shown in Figs. 4-7 respectively. This machine is a displacement based UTM for tensile testing. Loading is applied at a displacement rate of minimum 2 mm per minute to a maximum of 10 mm per minute as shown in Table II.

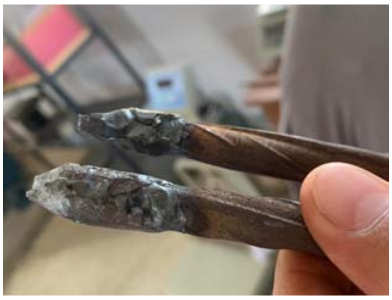
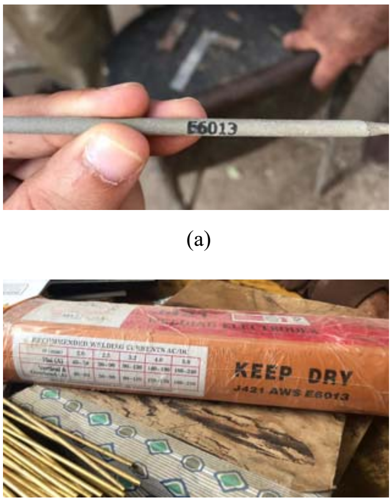


Fig. 2 Sizes of Weld Used



(a)

(b)

Fig. 3 Electrode Used for Welding

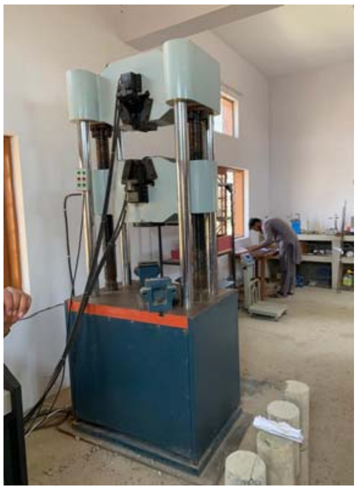


Fig. 4 Employed UTM

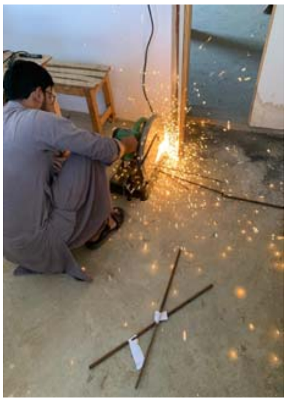


Fig. 5 Preparation of Samples

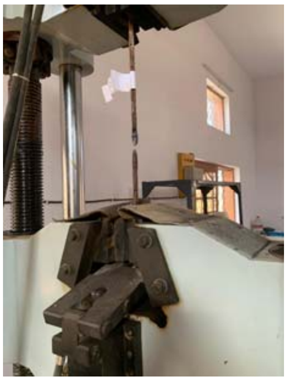


Fig. 6 Testing Setup

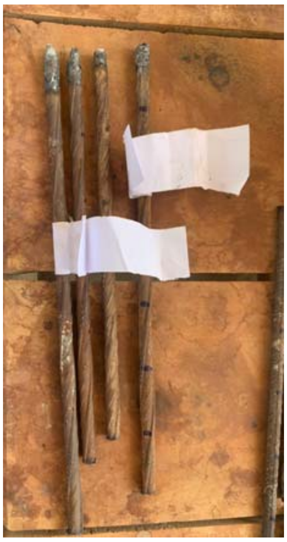


Fig. 7 Tested Specimens

IV. Results & Discussion

The results of tests performed are summarized in Tables I-III. The idea of using welded, cut pieces of steel reinforcement is based on the premise that if the failure of specimens from welded joint is prevented, i.e. a brittle failure; the specimens would then eventually fail from within the body of bars and this would result in a ductile failure whereas, extent of ductility would depend on the ductility of joining bars.

From observing the failed specimens (Figs. 6 and 7), it is evident that the specimens where the thickness of weld is set equal to bar diameter failed from welded joint. Specimens having a thickness of weld greater than bar diameter were broken from within the body of bar and the failure crack in the bar body was formed near the welded region. In addition, it is evident that these welded spliced bars are found to be satisfactory in its yield strength with the average of 58.7 ksi which is approximately close and similar to designated steel strength of 60 ksi. Satisfactory ultimate strength is also observed here with an average UTS of 78.3 ksi.

TABLE II
Details of Loading Rate and Strength Achieved

Sample No.	Bar Dia. (Inch)	Rate of loading (mm/min)	Yield Strength (lb/sq.in)	Ultimate Strength (lb/sq.in)
1	3/8	5	63060	84080
2	3/8	5	48963	65284
3	3/8	5	58271	77695
4	3/8	10	62867	83822
5	3/8	10	70562	94083
6	3/8	2	58770	78359
7	3/8	20	55586	74115
8	3/8	10	57662	76883
9	½	10	53250	71001

TABLE III
Elongation and Ultimate Strain Achieved

Sample No.	Bar Dia. (Inch)	Rate of loading (mm/min)	Elongation (%)	Strain (%)
1	3/8	5	6.3	38.4
2	3/8	5	1.3	15.2
3	3/8	5	2.5	21.33
4	3/8	10	2.5	23.87
5	3/8	10	6.3	36.47
6	3/8	2	3.8	27.5
7	3/8	20	5	21.85
8	3/8	10	3.1	33.6
9	½	10	2.5	21.6

The average elongation of specimens failing from welded joint is 2.96% showing a brittle failure and the average elongation of specimens failing from other than welded region is 6.3%, comparatively a ductile failure result.

V. Conclusion

It is concluded that, test result of welded spliced bars are found to be satisfactory in its YS and UTS. Some important conclusions for welding of bars are:

1. Failure of welded joint is prevented by using a greater weld size compared to bar diameter.
2. Elongation achieved in specimens with greater weld size is greater than the elongation achieved in specimens with weld size equal to bar diameter.
3. Maximum elongation reached is not as per that recommended by design codes (min. 10%) but is near to

that range.

4. Brittleness of welded region is observed in terms of closeness of failure crack in the welded area.

For further investigation, it is recommended that emphasis be placed on:

1. Designing of welded joints for producing ductile failure
2. Finding the appropriate size of weld for different bar diameters
3. Standardization of typical welding technique is necessary for achieving uniform test results

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