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Comparison of Structural Adhesive Joint with Spot and Seam Welded Joints

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Abstract - *Structural adhesives provide a permanent flush type joint between two sheets without any obstructions. These join two thin sheets of equal, unequal thicknesses or join two dissimilar metallic sheets. Structural adhesives are replacing conventional joining methods such as welding, riveting and bolting because of number of inherent advantages. These are cost effective reducing the number of mechanical fasteners and surface preparation, free of any defects, aesthetic improvements over* welding *and mechanical fasteners, reduce stress concentrations, improve the strength of the materials being joined, spread the load more uniformly over the entire bonded area, reduce the chance for rust and corrosion, reduce the distortions or splitting because of absence of screw, bolt and rivets holes, cause no weakening of the material because of excessive heat in welding, increase fatigue and force resistance by increasing the stiffness of structures, reduces the overall weight of the assembly by not using heavy welding metals and mechanical fasteners, can be pre-applied to parts otherwise inaccessible to mechanical fastening, compensates for differences in the expansions and contractions of dissimilar materials, form resilient bonds and maintain its strength over a wide range of temperature of -51^{0}C to 121^{0}C.Thus use of structural adhesives is swelling day by day over a wide range of industrial and other applications because of high strength and inherent advantages. Experiments were conducted to compare the strengths of structural adhesive joints with spot and seam welded joints under the operating parameters namely materials used were 2mm and 3 mm cold rolled coil annealed (CRCA) and hot rolled coil annealed (HRCA) steels, Overlaps of 12.5, 25, 37.5 and 50 mm. However sample length and width in each case was 180 mm and 25 mm respectively. Total number of samples tested on the Universal Testing Machine was 24.* **SikaPower®-4588** *adhesive was used in the present investigation. The outcomes of the experimental finding are structural adhesive joints were the best in many cases and were encouraging in the remaining cases indicating replacement of conventional joints with the adhesive joints is a matter of time only.*

Keywords: Structural adhesive joint, spot and seam welded joints, overlap, bond strength, thin sheets.

1. INTRODUCTION

Metallic thin sheets are widely used in all types of industries and can be joined by the different methods such as welding, riveting and bolting. But all these methods have inherent disadvantages of welding defects, distortions, stress concentrations, requiring more and skilled labor, more time consuming and more rejections of the finished assemblies. An alternative to these is the use of an adhesive joint. Adhesive bonding as a method of joining has a very long history and dates back to ancient times. Glues of animal origin, especially bone, hide and casein glues, were used quiet commonly. Common masonry mortars were essentially glues. This present study investigates the comparison of structural adhesive joints with spot and seam welding joining thin sheets. Structural adhesive-bonding provides several advantages over welding, riveting and bolting methods, such as reduction of stress concentrations, reduced weight penalty and easy manufacturing. Commercial structural adhesives range from strong and brittle to less strong and ductile ones. Various researchers have already advocated the use of adhesive joints instead of conventional joining of thin sheets [1-9].Thin sheet metal panels are joined with spot or seam welding depending on type of component & the nature of stiffening or strength required based on its intended function. But during the welding process, the spot welding marks become visible on outer surface & also distortions are observed which sometimes make the part unfit for use due to aesthetic requirements. To improve the quality of such joints, lot of rework is done by grinding/buffing on the outer surface to minimize unwanted visible defects. This reworking process on finished product is very time consuming & results in productivity loss due to high level of rejections. To take care of quality & productivity issues, the evolving technology is to paste the sheet metal parts with structural adhesive instead of spot or seam welding. In the present study, experiments have been performed for the comparison of performance analysis of adhesive joint over spot and seam welding. The various variable performance parameters are different types of material (Cold and hot rolled steels), different thicknesses (2mm and 3 mm),type of joining processes(adhesive, spot and seam welded

joints) and different overlap sizes (12.5, 25,37.5 and 50 mm).

2. DIFFERENT METHODS OF JOINING SHEET METAL

Figure 1 shows various methods of joining two materials.

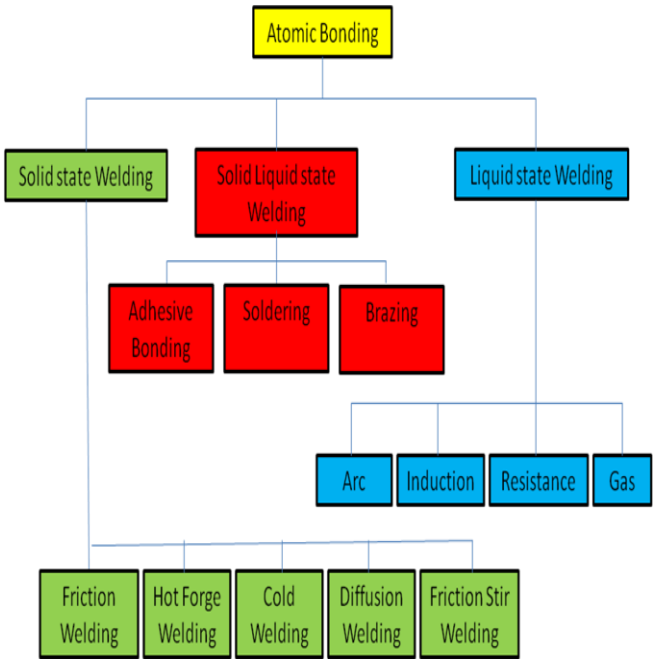

Figure 1: Sheet Metal Joining Processes

3. ADHESIVE JOINING TECHNIQUE OF SHEET METAL

"Adhesion" is derived from the Latin word "adhaesio" i.e. tacking or joining. It is a complex surface phenomenon. Adhesive is an organic or inorganic substance that is capable of permanent joining of materials as a result of various physical or physicochemical phenomena. Adhesives can be single- or multi-component preparations. These use polymers along with fillers and carriers. Adhesive joint is made by spreading the adhesive on the overlap area and given time for maturing. The various structural adhesives used are epoxies, acrylics and polyurethanes. In structural adhesive bonding, elements of a structure are fastened to one and another with an adhesive. For effective bonding, the adhesive must completely wet the surface of each substrates being joined. Structural adhesive bond must be capable of transmitting structural load without loss of structural stability within the design limits. It is achieved by transmitting forces from one member to another by more uniform distribution than that can be achieved with conventional mechanical fastening methods. Consequently, adhesives often permit the fabrication of structures that are mechanically equivalent or stronger than conventional assemblies, at a much lower cost and light weight.

4. DIFFERENT TYPES OF ADHESIVE JOINTS

The basic requirement of any joint between two or more components is to carry load effectively. The following are the various types of structural adhesive joints and geometries shown in figures 2 and 3 respectively.

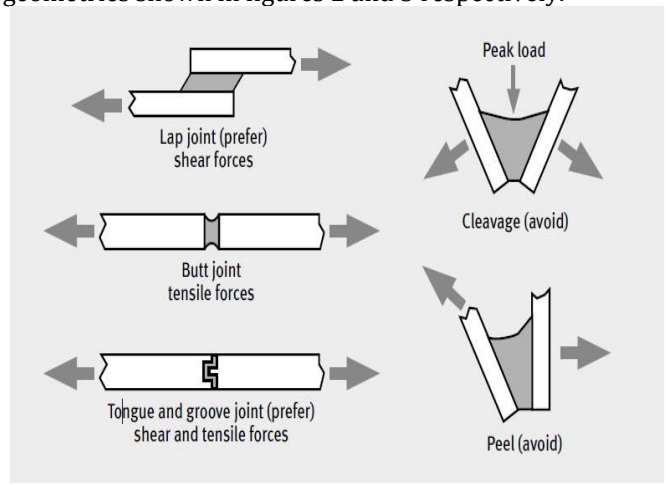

Figure 2: Various types of adhesive joints under different loadings

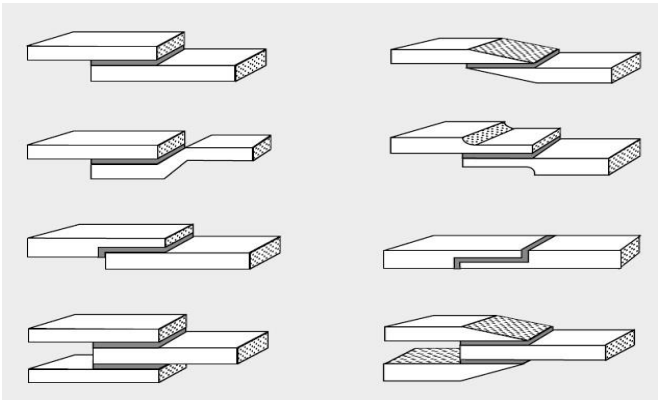

Figure 3: Possible Structural Adhesive Geometries to Enhance the Bonding Area.

5. LIST OF STRUCTURAL ADHESIVES

The following materials are being used as structural adhesives. These may be in paste, liquid, film, pellets and tape form**.** Such adhesives have high strength, long life and dependability by preventing contact corrosion and thus are suitable for structural applications.

(i) Epoxies find wide applications in the automotive, construction, heavy engineering, transport, electronics industry
(ii) Cyanoacrylate - locking, sealing and retaining applications
(iii) Polyurethanes find applications in Automotive, Coatings and adhesives
(iv) Acrylic adhesives- suggested for bonding metals, plastics, wood and glass
(v) Polyimides - automotive industry and aerospace to industrial applications and office machines.

6. STRUCTURAL ADHESIVE SAMPLE PREPARATION

Lap joint sample specimens were prepared with different thickness panels i.e.2mm & 3 mm in cold rolled coil annealed (CRCA) and hot rolled coil annealed (HRCA) steels by varying overlap sizes using **SikaPower®-4588** Structural metal adhesive(epoxy) was applied by standard electric or pneumatic piston operated pumps. The adhesive is applied in a bead form with a recommended diameter of 6 mm. Adhesive paste was applied at room temperature. The curing time was 24 hours and it was ensured that there was no blister formation. The thickness of the adhesive was limited to 0.05mm–0.15mm to avoid any seepage in a thick layer. And it was found sufficient for full wetting of the surface.

7. STRUCTURAL ADHESIVE SPECIMENS

Specimens of adhesive joint, spot and seam welding were prepared with the following performance parameters.

(i) Materials used were cold rolled close annealed (CRCA) and(hot rolled close annealed (HRCA) steels
(ii) Thicknesses used were 2mm and 3mm
(iii) Overlaps of 12.5, 25, 37.5 and 50 mm
(iv) Sample length and width in each case was 180 mm and 25 mm respectively
(v) Total numbers of samples for 2 mm thickness only were 24 which were tested on the Universal Testing Machine.
(vi) **Sika Power®-4588** Structural metal adhesive (epoxy) was used in the present investigation.

8. DIFFERENT SPECIMEN SIZES

Detailed sizes of adhesive, spot and seam welded joints are shown in figures 4, 5 and 6. Their dimensions are given in tables 1, 2 and 3. Total number of sample was 48, 24 each for 2mm and 3mm thicknesses respectively.

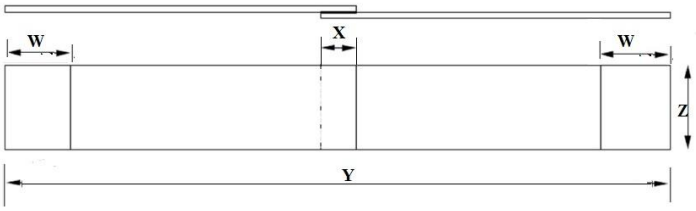

Figure 4: Structural Adhesive Specimen Diagram

Table 1: Dimensions of Structural Adhesive joints

Sample No.	X (Overlap Size in mm)	Y (Sample length in mm)	Z (Sample Width in mm)	W(Holding strip width in mm)
1	12.5	180	25	25
2	25	180	25	25
3	37.5	180	25	25
4	50	180	25	25

Figure 5: Spot Welding Specimen

Table 2: Dimensions of spot welded joints

Sample No.	X (Overlap Size in mm)	No. of Spots	Spot Diameter (in mm)	Spot Pitch (in mm)	Distance From Edge (in mm)
1	12.5	2	6	12	3.5
2	25	3	6	12	3.5
3	37.5	3	6	12	3.5
4	50	5	6	12	3.5

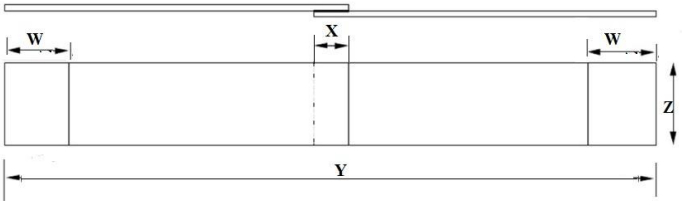

Figure 6: Seam Welding Specimen

Table3: Dimensions of seam welded joints

Sample No.	X(Overlap Size in mm)	Y(Sample Length in mm)	Z (Sample Length &Width in mm)	No. Of Seam Weld Layers	Seam Layer Width in mm	Seam Layer Length in mm
1	12.5	180	25	1	6	25
2	25	180	25	2	6	25
3	37.5	180	25	2	6	25
4	50	180	25	2	6	25

9. LOAD VS DISPLACEMENT FOR CRCA HAVING 2mm THICKNESS

Load vs displacement are shown in figures 7, 8 and 9 respectively for adhesive, spot and seam welded joints.

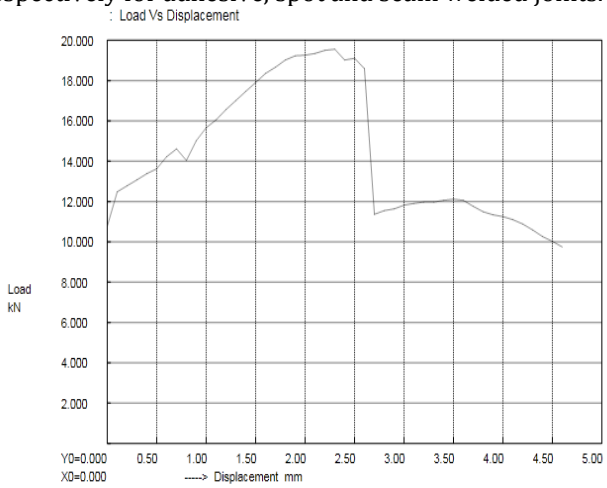

Figure 7: Load/Displacement Graph for Structural Adhesive with overlap size 25 mm

Overlap (mm)	Displacement (mm)	Load (kN)
25	4.6	19.5

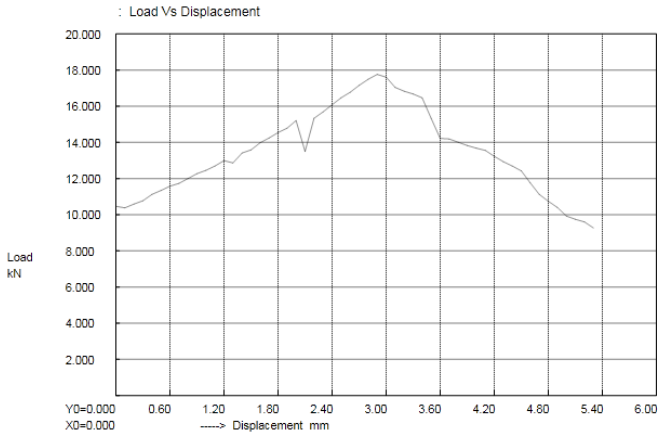

Figure 8: Load/Displacement Graph for Spot Welding with overlap size 25 mm

Overlap (mm)	Displacement (mm)	Load (kN)
25	5.1	17.7

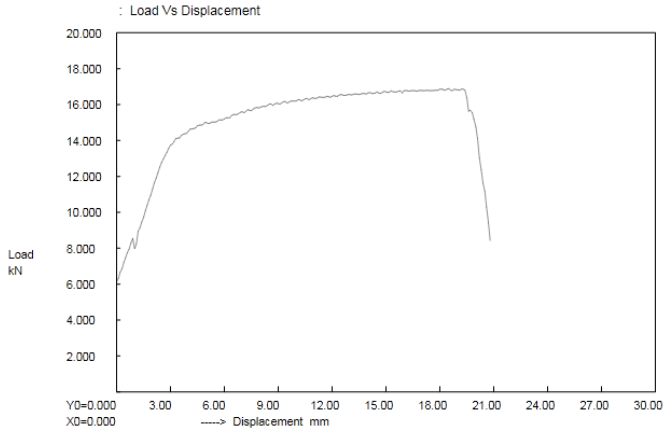

Figure 9: Load/Displacement Graph for Seam Welding with overlap size 25 mm

Overlap (mm)	Displacement (mm)	Load (kN)
25	20.8	16.8

10. COMPARISON OF JOINTS STRENGTH OF CRCA (2mm thickness):

Overlap	Adhesive joint	Spot welded joint	Seam welded joint
12.5 mm	13.30 kN	15.00 kN	9.96 kN
25 mm	19.50kN	17.70 kN	16.80 kN
37.5 mm	21.20kN	18.90 kN	17.20 kN
50 mm	24.70kN	22.60 kN	25.20 kN

11. LOAD VS DISPLACEMENT FOR HRCA HAVING 2mm THICKNESS

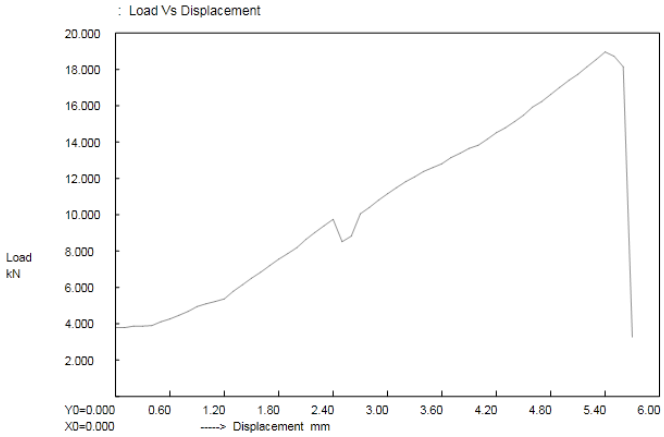

Figure 10: Load/Displacement Graph for Structural Adhesive with overlap size 37.5 mm

Overlap(mm)	Displacement (mm)	Load (kN)
37.5	5.7	18.9

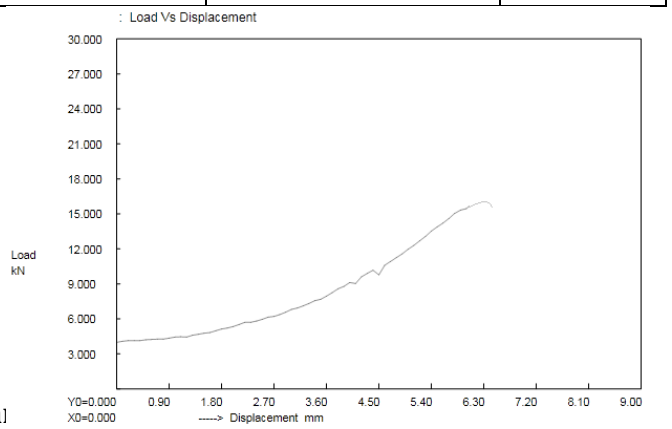

Figure 11: Load/Displacement Graph for Spot welding with overlap size 37.5 mm

Overlap (mm)	Displacement (mm)	Load (kN)
37.5	6.5	15.4

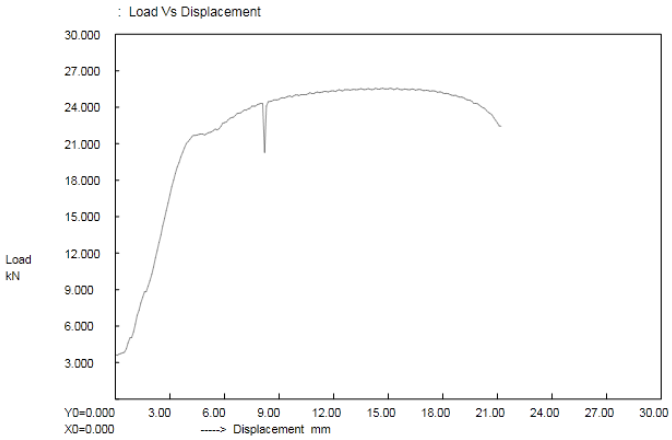

Figure 12: Load/Displacement Graph for Seam Welding with overlap size 37.5 mm

Overlap (mm)	Displacement (mm)	Load (kN)
37.5	21.2	25.59

12. COMPARISON OF JOINTS STRENGTH FOR HRCA (2mm thick)

Overlap	Adhesive joint	Spot welded joint	Seam welded joint
12.5 mm	10.29 kN	9.91 kN	21.57 kN
25 mm	13.80 kN	11.97 kN	16.00 kN
37.5 mm	18.90 kN	15.40 kN	25.59 kN
50 mm	24.70 kN	22.20 kN	22.10 kN

13. COMPARISON OF SHEAR STRENGTH WITH 2MM CRC

Figures 13 and 14 shows the shear stress vs overlap in different joints.

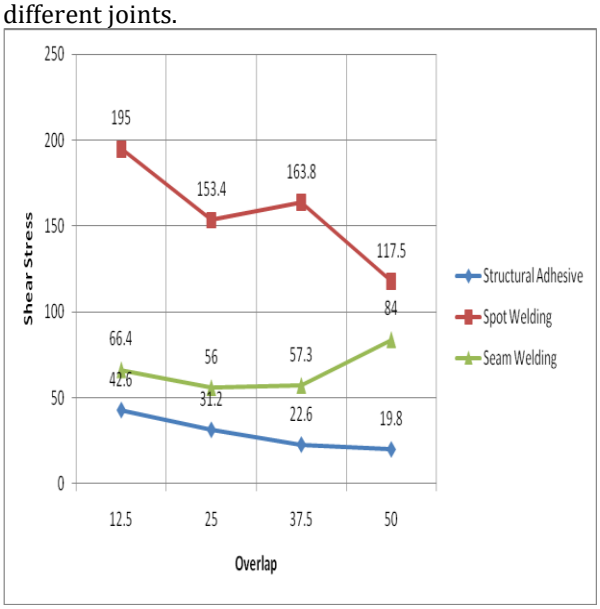

Figure 13: Shear Stress v/s overlap results of structural Adhesive, Spot Welding and Seam Welding with 2mm CRC material

15 COMPARISON OF SHEAR STRENGTH WITH 2MM CRC

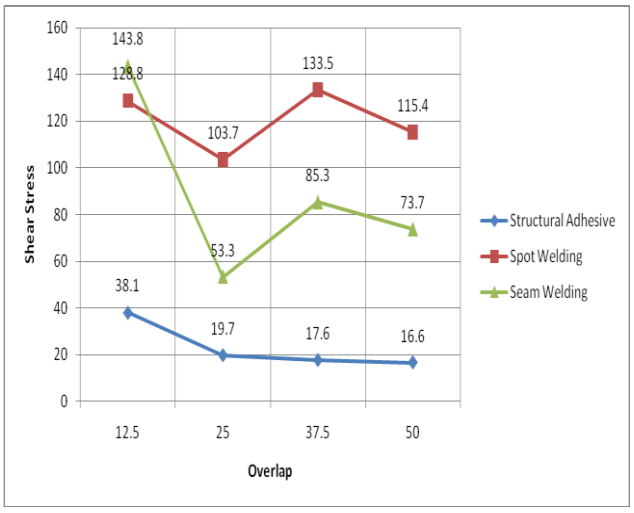

Figure 14: Shear Stress v/s overlap with 2mm HRC material

14. RESULTS AND DISCUSSIONS

(A). The following conclusions have been drawn for the cold rolled steel

(i) Force required breaking the joint increases with the increase of overlap size for the adhesive, spot and seaming welded joints.
(ii) Force required was highest for adhesive joints with overlaps of 25 and 37.5 mm.
(iii) For an overlap of 12.5 mm, spot welded has the maximum force, then is adhesive and seam welded joint.
(iv) For an overlap of 50 mm, seam welded joint has the maximum force, then the adhesive and spot welded joint.

(B). The following conclusions have been drawn for the hot rolled steels

(i) Force required increase with the increase of overlap in case of adhesive and spot welded joints. However a mixed behavior was observed for the seam welded joints.
(ii) For 50 mm overlap, adhesive joint was the best.
(iii) For the overlaps of 12.5, 25 and 37.5 mm shows highest force for seam welding then adhesive joint and spot welded joint respectively.

15. CONCLUSIONS

Sheet metal samples were made by spot welding, seam welding and structural adhesive but their shear strength varied with types of joining processes, overlap size, type of material and their thicknesses. From the experimental results, the following conclusions have been drawn:

(i) Joint shear strength varies with the joining process; shear stress developed is less spot welds and structural adhesive joints as compared to seam welded joints.
(ii) With an adhesive joint and spot welding, shear strength of 2 mm cold rolled coiled annealed steels (CRCA) is more than 2 mm that of hot rolled steels (HRCA).
(iii) With a seam welding, shear strength of 2 mm cold rolled coiled annealed (CRCA) material is less than 2 mm HRCA material.
(iv) For structural adhesive, the shear strength decreases with increase in overlap size.
(v) The overall conclusion is adhesive joints are best with certain overlaps and quite promising with other overlaps. More research in this direction is likely to bring better results in favour of adhesive joints as compared to spot and seam welded joints. In addition, adhesive joints have number of inherent advantages over welded, riveted and bolted joints. Hence adhesive joints are likely to replace welded and other joints.

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