

Field experience section

PRESSURE - GAS BUTT WELDING OF REINFORCING BARS

I. C. Armstrong* and W. J. Page

1. Introduction

Detailing for ductility in reinforced concrete earthquake-resistant structures and the risk of non-ductile failure at lap splices of the larger sizes of reinforcing bars have resulted in increasing use of full-strength butt welds of reinforcing bars. The benefits to be gained from eliminating long lengths of lapping bars and reducing serious congestion are overshadowed, however, by the time and cost (both direct and indirect) involved in making arc welds on site and the necessity for special supervision and testing of the work.

The pressure gas welding process consists of heating the bar ends with a multi-jet oxy-acetylene torch while the end surfaces are butted together under pressure in a bar clamp unit (Fig. 1). Time of heating and applying pressure is 3-4 minutes. This faster, more economical technique, which is widely used in Japan for butt-welding reinforcing bars over 19 mm (3/4") diameter, offers a promising alternative to manual arc welding for both shop and site.

The Ministry of Works Structural Design Office introduced the process into New Zealand and has guided development of equipment and techniques for bar end preparation, flame setting and pressure application suited to local conditions. A bar clamp unit and information obtained from Japan assisted this work. This method of welding is being used on the construction of an eight-storey shear core building. The Ministry, which makes wide use of butt welded splices in aseismic detailing of reinforcement, now accepts the pressure-gas process for bars to N.Z.S. 1693 as an alternative to arc welding and expects its use on several projects soon to be constructed.

*Design Engineer and +Engineer,
Structural Design Office, N.Z. Ministry of Works, Wellington.

2. Solid-Phase or Recrystallization Welding

The pressure gas process requires clean, freshly surfaced bar ends to be closely butted together and joined by applying heat and pressure while substantially excluding air from the interface, under conditions such that no liquid phase is produced at, or introduced into, the joint.

The mechanism of bonding in the solid phase requires that non-metallic contaminant films (mainly oxide) be removed from the interface and that the resulting chemically clean surfaces be brought into intimate metallic contact. (These two functions are performed in arc welding by the molten metal, aided in contaminant removal by use of a flux.)

The final stages of heat and pressure application during welding produce complete contact between the softened end surfaces, followed by upsetting in the weld plane (Fig.1). The bar end preparation and flame setting procedures ensure that only thin films of oxide are present, and these films tend to diffuse away from the interface during heating. The remaining oxide films are ruptured by deformation of the softened metal and enlargement of the interface area during upsetting; the oxides form globules (due to surface tension) and may further diffuse away. The metal surfaces are now chemically clean, and unite by intimate contact in the solid phase.

During cooling in air from the maximum temperature of about 1100°C - 1200°C , bonding is accomplished by a solid phase transformation which promotes recrystallization (grain growth) in the weld zone. This grain growth between the metal surfaces can proceed to such an extent as to eliminate the original interface.

A good weld can thus be said to be one in which the weld plane is not evident under micro-examination.

3. Equipment

For butt welded splices of reinforcing bars by the pressure gas method, the following equipment is employed:-

- (1) A multi-jet oxy-acetylene torch (Fig. 2), connected by a standard short hose length to a gas metering control unit which allows a constant flame to be set. The torch must travel and rotate sufficiently to heat uniformly the whole bar circumference over a length of half the bar diameter on each side of the weld plane.

- (2) A bar clamping and hydraulic pressure unit (Fig. 3) clamps the bar ends in relative alignment. A hand-operated hydraulic pump with pressure gauge controls the pressure which acts through a movable clamp block to apply the required butting pressures at the bar ends.
- (3) A gas metering unit employs gauge readings to control setting of the reductive flame required.
- (4) A hand-operated hydraulic pump with pressure gauge. This must properly control the applied pressure as the bar ends become softened on heating.
- (5) A simple timing device, e.g. a slowly rotating disc marked with coloured sectors appropriate to the timing cycle in use.
- (6) Bar cutting (square sawing) equipment.
- (7) Equipment for freshening or dressing of bar end surfaces, using filing or clean light grinding.

A view of the equipment on scaffolding, during welding of vertical core wall bars in place, is shown in Fig. 4. Gas cylinders on the ground or on a completed floor level are connected by any suitable length of hose to the gas metering device on the scaffold. Bars to be spliced are sawn square on the ground and then hoisted to the working level. Two or three clamp units can keep one torch unit in full use.

4. Bar End Preparation

A high standard of bar end preparation is essential to ensure that oxide film on the end surfaces is sufficiently thin to break up into globules and tend to disperse away during upsetting. Departure from this high standard will result in inconsistent welding, particularly under the variable atmospheric conditions encountered on site.

- (1) Surface Freshness: The bar ends at the time of welding must be clean and have a fresh metal surface substantially free of oxide film. End surfaces may be sawn without overheating or otherwise freshened by filing or light grinding, provided always that welding is completed within a maximum time interval of half an hour from such sawing or surface dressing. Light grinding should be executed with care to avoid overheating with its characteristic blue oxide formation.

- (2) Surface Geometry: The bar ends must be square to the bar axis when set up in the clamp, to ensure close butting surfaces (Fig. 5).

5. Flame: Exclusion of Air

In addition to the minimizing of oxide film on the end surfaces just prior to welding (by surface freshness), it is essential to prevent access of air to the interface (which would cause rapid oxidation of the heated metal) while welding is in progress. Close butting of end surfaces under pressure assists this, but exclusion of air is mainly obtained by use of a reductive "excess-acetylene" flame. This flame is adjusted by means of the gas metering unit so that the tip of the pale blue "feather" is just clear of the bar surface during initial heating (Fig. 5).

6. Welding Procedure

Heating is commenced under an initial pressure of 1000 psi at the hydraulic pump, and the weld area reaches red heat with the end surfaces softening after 2 minutes. Pressure is increased to an intermediate value of 3000 psi and held about 30 seconds to close slight gaps between the bar ends and produce complete contact between the softened surfaces. Finally, pressure is increased to about 3,800 psi and heating is maintained while up-setting of the weld area takes place. When the diameter of the bulge reaches 1.3 times the bar diameter, heating is terminated while the final pressure is maintained until the bar has cooled sufficiently. (Note: pressures and times refer to No. 10 bars and the equipment shown in the illustrations.) The completed weld is shown in Fig. 6.

7. Testing

Direct tensile tests, nick-break tests and bend tests were used to check weld quality during early investigations. However, defective welds, which would fail the bend test, often allowed a bar to develop full strength in the tensile test due to increased area at the upset. The 180 degree bend test, using a diameter of bending former equal to three times the bar diameter and with the upset machined off the weld before testing, proved to be the most satisfactory acceptance test for weld quality. That bend test has been adopted.

The procedures developed were checked for consistent results; and a total of 86 test welds of bars to NZS 1693 were made by several operators, comprising welds in 7 No.8,

14 No.9, 53 No.10 and 12 No.12 bars, of which one only weld (a No.12 bar) failed the bend test. Metallurgical examination of two samples showed the welds to be uniform and sound save for some microporosity.

The first full-scale application commenced in September 1968 on the construction of an eight-storey reinforced concrete building with central shear core at Massey University. That work requires approximately 3,400 butt welds of Nos. 7,8,9,10 bars to NZS 1693, 75% being welds of No.10 bar size. Of the total number, half are welds in foundation beams (longitudinal bars and heavy stirrups) and half comprise mainly vertical bars in the shear core walls.

Bend tests in the preliminary stages comprised 28 welder qualification and 40 procedure tests (two series), all tests being successful. Acceptance tests covering the foundation beam welds comprised 35 bend tests from shop-welded stirrups and 17 tests from longitudinal bars welded at a bench on the site, none of these tests having failed. With construction of the core walls presently proceeding, all of 16 acceptance tests taken from vertical bars welded in place, from scaffolding, have passed the bend test.

General conclusions from the construction work to date are that welds are consistently good provided the high standards of bar end preparation are maintained; however any deviation from these standards appears to introduce inconsistency which will affect the standard of reliability of site welds produced by the process.

8. Acknowledgements

Mr G.H.F. McKenzie, Assistant Chief Structural Engineer, Ministry of Works, in the course of an overseas visit investigating welding procedures in general, first reported on the use of pressure gas welding in Japan, and assisted with the development.

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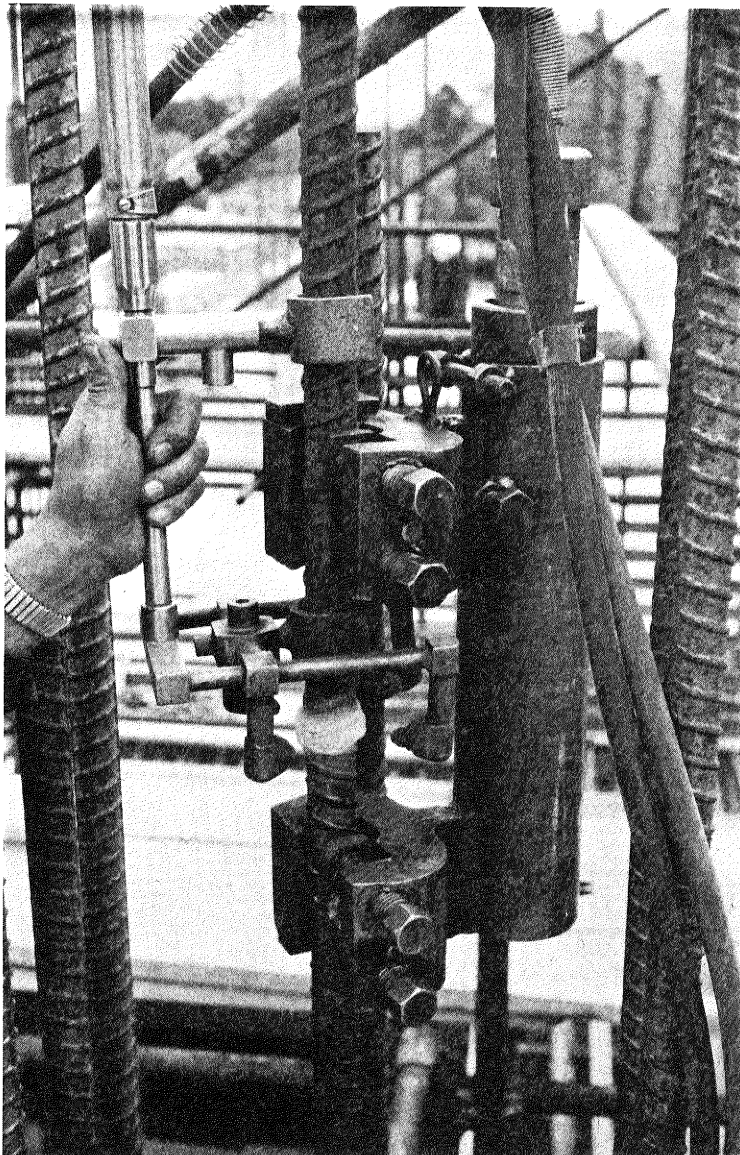


Fig. 1. Multi-jet oxy-acetylene torch and bar clamp unit at completion of welding..



Fig. 6. The completed weld.

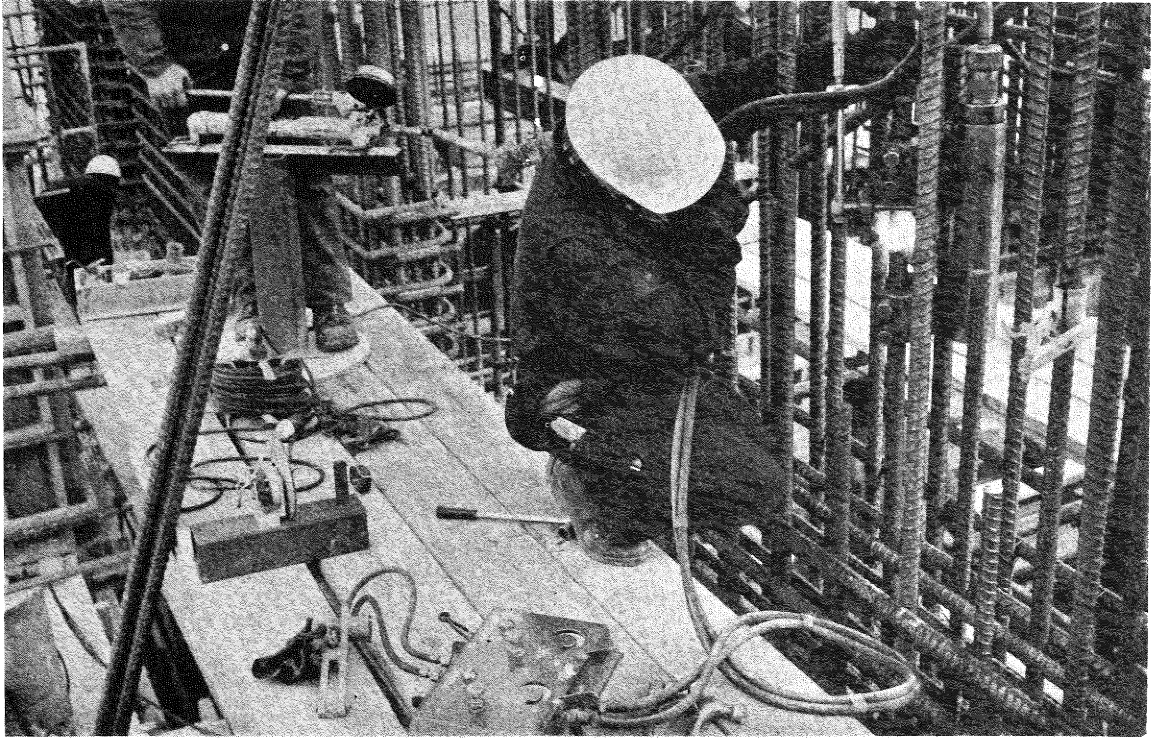


Fig. 4. Pressure-gas equipment on scaffold during site welding of wall bars.

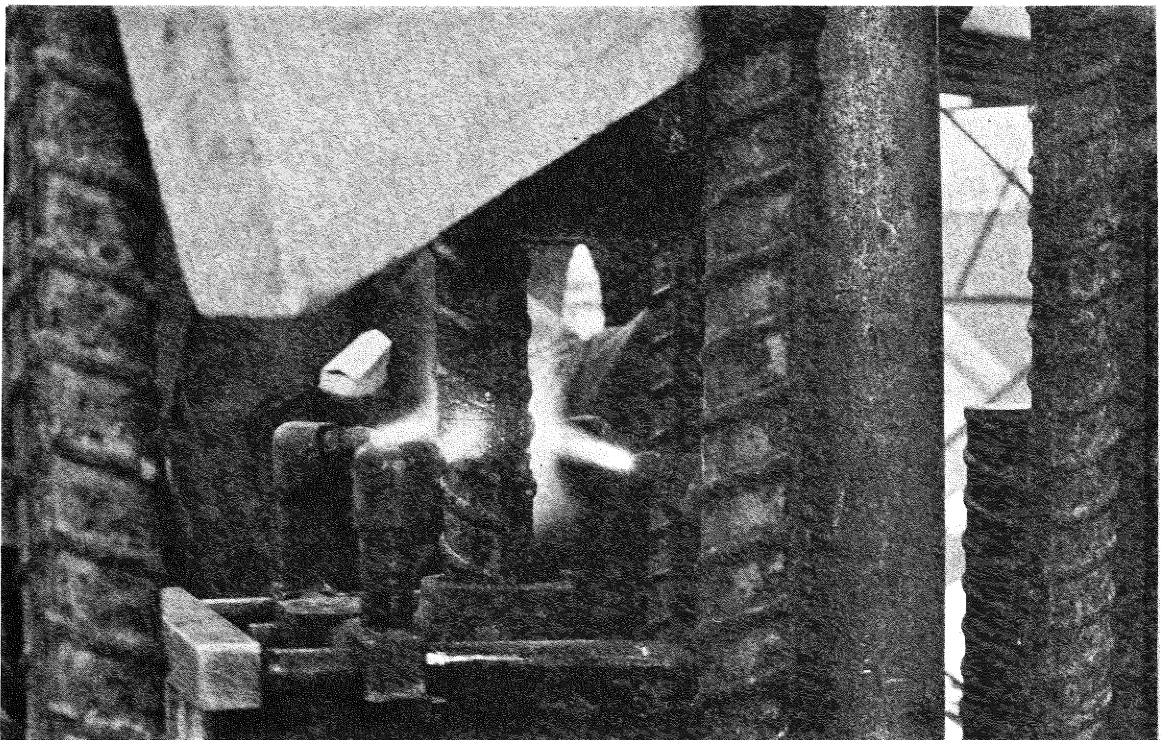


Fig. 5. Commencement of heating. Note the close butting of bar end surfaces, and "feather" of reductive flame.

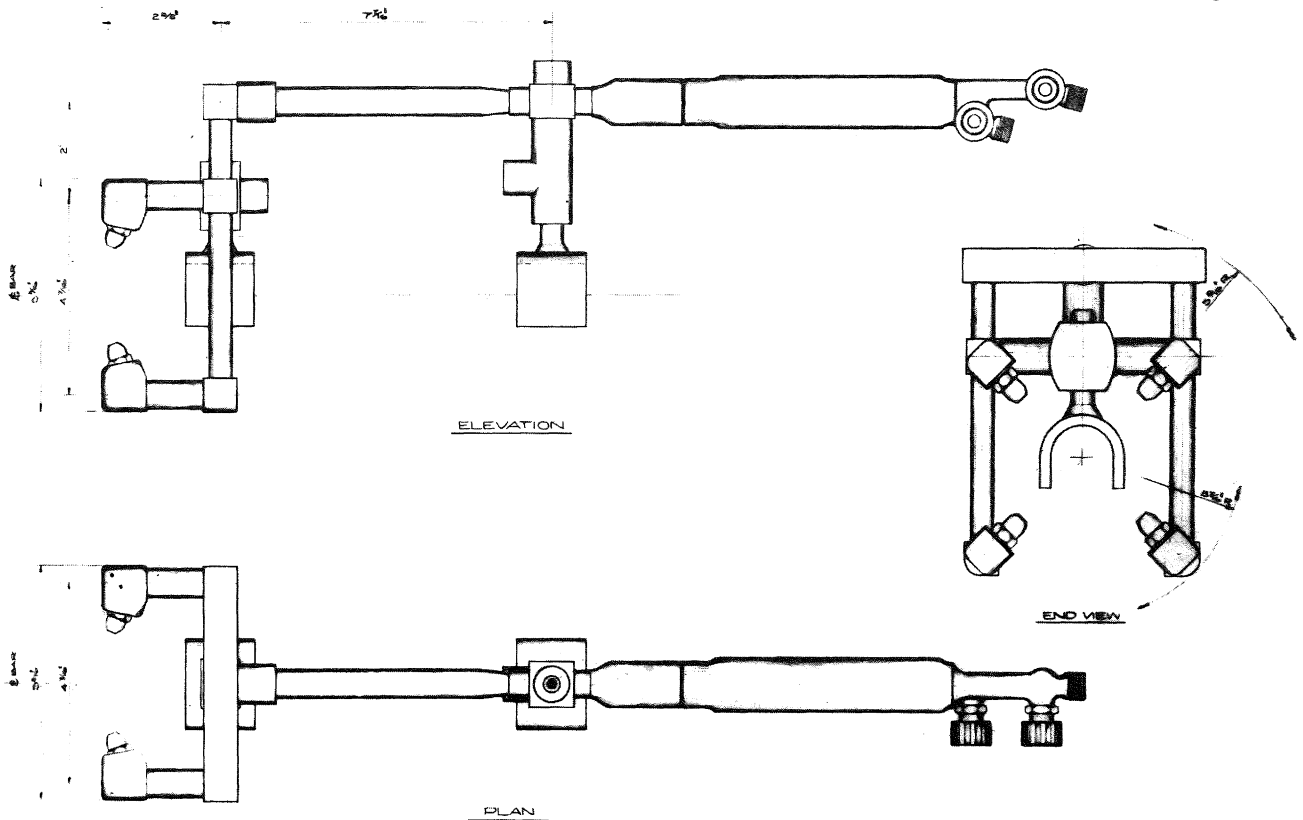


Fig. 2. Four-jet oxy-acetylene torch unit.

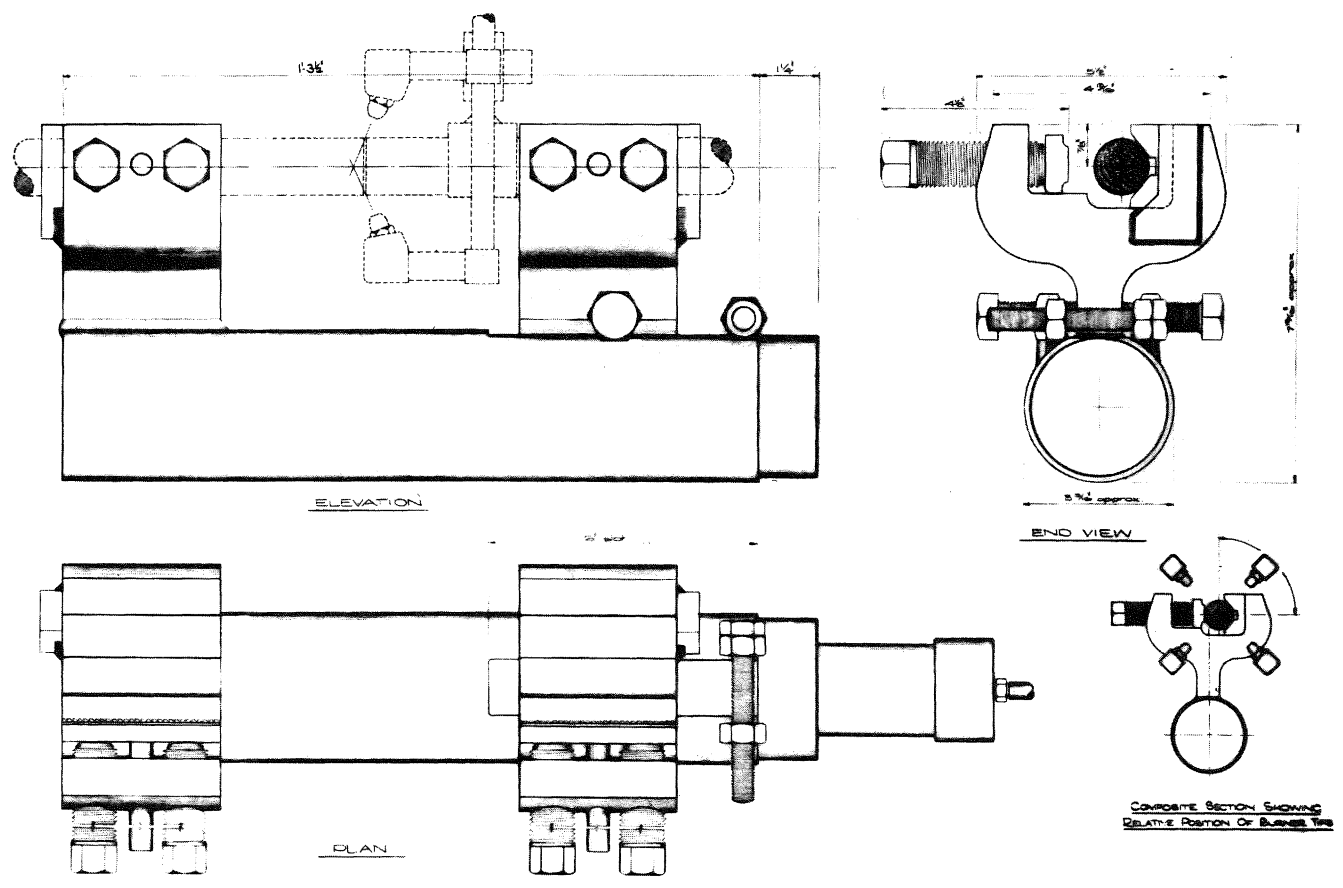


Fig. 3. Bar clamp and Hydraulic Pressure Unit.