Reliability Assurance in Navy's Welded Steel Shore Structures*

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ASIDE FROM ships, the Navy construction program covers a wide variety of welded steel structures built on shore, as well as certain types of floating craft in harbor installations. The construction of these structures is under the jurisdiction of the Naval Facilities Engineering Command. In the past, this command, then known as Navy's Bureau of Yards and Docks, had its own codes and standards for workmanship and acceptance. Although these standards contained only minor deviations from the corresponding specifications of the private industry, in recent years a new policy has evolved which, in effect, has resulted in full conformance with current regulations of commercial practice.

Government construction agencies are often criticized by the building industry for their unnecessarily restrictive specifications, which they rightly contend to have contributed to mounting costs of fabrication. Rarely a project is completed without involvement in interpretive litigation. Perhaps influenced by this situation, the industry itself is now adopting many of these restrictive clauses. This is particularly true for regulations governing welded construction, and more specifically, the quality and acceptability of welds, which are covered mainly by the American Welding Society's *Code for Welding in Building Construction.*

THE OLD CONCEPT OF RELIABILITY ASSURANCE

For the discussion of this rather thorny problem of weld acceptability, some background information would be helpful. Since the inception of fusion welding, all concerned with its use have been well aware of the many flaws which may result from the mechanics of application of the process. Most of these flaws become visually apparent in the weld deposit, some in the form of contour or profile defects, such as excessive convexity or concavity, lack of penetration and fusion, overlapping and undercutting, and others as near-surface inclusions, craters, shrinkage cracks, blowholes, and porosity. By visual inspection, often aided by lights and magnifiers, little difficulty is experienced in the detection and repair of these defects. What remains difficult to resolve pertains to the flaws which are concealed in the body of the weld and, hence, need special devices for their detection.

It is interesting to note that the early editions of the American Welding Society's Building Code[1] contained no special provisions for either the acceptable extent or the method of detecting hidden weld flaws. Instead, it specified that the weld shall be "sound," and required layer-by-layer weld inspection through inspectors possessing "demonstrated ability to distinguish between sound and unsound welding." On the other hand, apparently reconciling with the unavoidability of such flaws, the Code had then assigned lower working stresses for welds in tension, with the thought that they would be more adversely affected by the presence of defects. Later, in the light of numerous tests, which clearly demonstrated that the static strength of a welded joint with interior weld defects—of magnitudes far greater than those obtainable even in poor workmanship—is not impaired, this stress penalty for tension welds was dropped. In this move the American Welding Society followed, in effect, the earlier lead of the Bureau of Yards and Docks, which had not only eliminated allowable stress differentials for welds under tension and compressions in its specifications, but also had sanctioned the use of incomplete penetration welds in certain joints of framing.

ADEQUACY VS. QUALITY

Despite the steady progress that has been made in welding technology, as reflected by the development and application of the many processes and techniques, and notwithstanding the continual introduction of improved materials and equipment for welding, as well as the ever-increasing know-how of the art, gradu-

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ally a new understanding has evolved whereby the weld is considered as a critical, if not hazardous, jointing medium requiring rigid and burdensome regulatory measures for its use. As a corollary, the emphasis has shifted from adequacy of performance to detection and control of flaws. This tendency, in turn, has rendered welded construction suspect, necessitating the adoption of onerous procedures for inspection, with the implicit thought that such measures are indispensable for the safety of the welded joint.

Obviously, no one would want to argue against the provision of what is truly needed for safety. What is debătable is the basis or definition of that requirement. If a satisfactory performance under actual service conditions, as obtained over long periods of observation, is made the basis of judgment, it may be said that a weld produced by average workmanship is adequate for the intended transfer of stress and, hence, should be considered as safe. Here, average workmanship is defined as the work of a qualified welder, performed under in-house contol or surveillance, and free of certain specified defects which are detectable by visual inspection. With rare exceptions, for the variety of types of welded steel shore structures, as well as for some auxiliary floating craft, built by the Navy's Bureau of Yards and Docks in the past, this was the procedure used.

This agency's experience in welded steel fabrication dates back to the late thirties and embraces a number of pioneering undertakings. For it includes the first all-welded floating structures of massive size in the form of drydock caissons and floating docks, and the first and largest all-welded industrial buildings and hangars. It is remarkable to reflect that the proven adequacy-in-service of these structures was obtained through average workmanship and the use of not-so-advanced technology then prevailing. And still more significant is the fact that, except for visual inspection and some cored coupon tests, none of the rigid and expensive procedures of quality control exercised today was used in those early applications. If the welding of these structures were now to be probed by the devices currently in use, few of them would be found acceptable on the basis of present code requirements.

NEW PROBLEMS IN WELD ACCEPTABILITY

With the advent of new methods of nondestructive testing, the problem of weld acceptability has been greatly complicated. The anomalous situation arises from the application of these devices to verify the soundness of the weld. Visual inspection is no longer considered adequate for this purpose and, for the first time, a tacit admission is given in the Building Code[2] for the necessitated use of other means for probing flaws concealed in the weld. This acquiescence is evident from two clauses. In one, it states: "When nondestructive testing is to be required as a part of the contract, it shall be so stated in the information furnished to the bidders." In the other, it gives the limits of "porosity- or fusion-type defects" for acceptability of welds that are "subject to nondestructive testing."

Contrary to expectations, the introduction of these statements into the Code has not been helpful for the needed clarification of intent and application. In fact, many new questions and controversies have arisen. Perhaps the most critical interpretation is that, before any weld can be considered sound or acceptable, its interior must be probed to ascertain that the detected flaws are within the specified limits. This could mean 100 percent inspection. Additionally, some of the owners of the welded structures, particularly government agencies, contend that no restrictions should be placed on their rights to demand such tests to any extent, and at any place or stage of construction. As for the cost, they indicate willingness to pay only for the test proper in the areas not specifically stated or covered by the contract, with the further provision that the tests disclose no defects beyond the range prescribed in the AWS Building Code. Because of probable interpretations of this nature, welded fabrication has become a costly process which a decreasing number of fabricators are willing to undertake. In the same frame of events, the owner's lot remains equally unenviable, for he is apt to share in the pain and cost of controversies, litigation, and delays.

THE DESIGNER'S RESPONSIBILITY

If maximum economies are to be realized in welded construction, code requirements should be introduced judiciously, and their execution carried out through a cooperative spirit of enlightened understanding. For the first part of the task, the engineer or designer of the structure bears a grave responsibility. Aside from the proper choice of framing material, geometry of assembly, jointing detail, and a careful analysis of structural response, which are normally assumed to be within his competence, he should be mainly responsible for the need and extent of the required subsurface probing of the weld—the most important single factor affecting welding cost. It is to be remembered that such probing is not mandatory by the Code. Here the provisions are given merely as a guide to define the type of the hidden defect and its magnitude for acceptability, to be used only when the performance of such test is called for by the job specifications. Except for some rare conditions of service loading which may occur locally, resulting in fatigue by the stress pulse and repetition, for the structures covered by the AWS Building Code, there is no justification for subsurface weld probing. With this thought, it becomes the engineer's duty not only to exercise the utmost care in specifying such tests, but also to see that their indiscriminate stipulations are eliminated from contract clauses.

In his long experience with the design and construction of welded steel shore structures, the author has seldom found it necessary to resort to nondestructive testing of welds for assurance of their strength or structural adequacy. In the case of auxiliary floating craft, such as pontoons, caissons and docks, he has utilized these tests, in their simplest forms, for the purpose of functional assurance rather than strength verification. The use of dye penetrants, to check oil-tightness, and compressed air and soap suds, for water-tightness, is predicated on that consideration. He also holds the firm belief that reliability in welded framings can be assured more effectively and at less cost through good visual inspection during fabrication than by conducting time-consuming and controversy-prone tests on the finished work.

REFERENCES

1. Code for Fusion Welding in Building Construction, *American Welding Society, 1930.*
2. Code for Welding in Building Construction *American Welding Society, 1966*, paragraph *607.*