5th Int. Conference Structural Integrity of Welded Structures (ISCS2007), Timisora, Romania, 20-21 Nov 2007
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From the Practice of Non-destructive Examinations at Steel Welded Joints in Civil Constructions

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Abstract
The use of steel in civil constructions has many advantages of which I mention the fact that the weight of the construction is more reduced which leads to smaller strains on foundations and gives a better earthquake performance. .
The welded joints used in civil constructions require, at the same time, to take some measures specific to the new technology. The strain of the welded joints can be also on the X direction, but in case of T welds the strain is on the Z direction. .
The methods of non-destructive examinations applied for the inspection of the welded joints are the visual examination, the ultrasonic examination, the magnetic particle examination, the liquid penetrant examination, and to a small extent, the radiographic examination. These examinations must be made by a staff who is qualified and certified in the field of the methods which he applies. The methods applied in certain cases are complimentary and cases from their use practice are presented.
Key words: civil constructions, welding, non-destructive examinations, visual, ultrasonic.

1. Introduction

The seismic events which took place in January 1994 at Northbridge in USA and at Kobe in Japan in January 1995, demonstrated that in countries with experience in constructions and in the norms for the anti-seismic design with metallic structure, respectively, some important damage was caused. The research which followed was based on the conception of the details of the metallic joints, as well as on their inspection on the structure assembly. As a result, the research design Copernicus "RECOS" – Reliability of Moment Resistant Connections of Steel Building Frames in Seismic Areas, took place in 1999 in Europe, where seven countries participated, among which was the team from the Construction Institute in Timisoara. The research made led to the improvement of the anti-seismic designing code Eurocode 8 (EN 1998-1).

A part of Romania's territory represents an area with high seismic risk, and the locality with the highest risk is Bucharest. After the earthquake in 1977 the seismic risk threshold has increased, which has led immediately to the recalculation of the constructions being built. The use of steel as a material for buildings represents a solution which leads to the decrease of this risk. The recent buildings in Bucharest are of two types, namely: *multifloored buildings*, made of braced heavy rolled steels, some with double structure, having up to 27 floors and *spaces* for commercial centers, small industry, warehouses, generally made of metallic beams specific for the constructions.

The ant seismic designing norm Eurocode 8 (2001) establishes the requirements for a correct designing which has mainly in view the protection of people's lives, with a limited degradation of the construction, with possible and limited repairs after an earthquake. Due to the random character of the seismic movement and to the actual behaviour of the structure, EC 8 leaves to the local authorities' the choice of the return period and the

exceeding probability for the earthquake. An earthquake has the exceeding probability of 10% and the return period of 95 years for the limit condition of work with limited damage.

2. Preliminary data

The structures in metallic frameworks are designed to meet the strength and stiffness requirements corresponding to the limit conditions for strong earthquakes, the energy being spread through plastic deformations to certain sections.

For the structures in metallic frameworks one must take into consideration the cyclic character of the movement and the decrease of the rotating capacity which appears in the joints submitted to cyclic strains.

The limit criterion is the strength to the plastic fatigue expressed under the form of unitary strain and number of cycles given by the formula:

$$\text{Log } N = \log a - m \log \Delta\sigma_g$$

where:

N the number of the distinct fields of a certain amplitude;

log a a constant;

m the slope of the fatigue strength curve with values of 3 to 5 depending on the level of the unitary efforts;

$\Delta\sigma_g$ the fatigue strength.

The fatigue inspection is made by evaluating the destruction index D deduced from the relationship: $D = n / N$

where:

n is the number of amplitude cycles $\Delta\sigma$;

N is the number of amplitude cycles $\Delta\sigma$ which cause the weakening.

The metallic structures are performant due to material ductility at cyclic strains, but at the same time the presence of discontinuities in the structure changes the data of the problem.

The quality is, mainly, based on two axioms which are tacitly assumed. The first one is the probability to fracture by *the increase of the size of the discontinuities* in the tested object. The second axiom is the probability of fracture by *the increase of the proportion of the volume occupied by discontinuities* (flaws) in the tested object.

3. The non-destructive examination

The non-destructive examination, abbreviated NDE, is a test without destruction and it represents a technological process implied in all the execution stages of a work, starting with the designing, the execution proper of the work and ending with the authority's inspection. The non-destructive examination uses, from the scientific point of view, the applications of the theoretical physics as concerns the computer technology for the quality level of the examined object.

Non-conformities were found out, on basis of the non-destructive examinations made at some constructions, in all the stages, from designing, supply, site organisation, work execution, use of staff with improper qualification, which will be partially studied in the next paragraphs.

The construction works must be made having as a basis a *designing which relies on performance* and this thing is made concrete through the norms which regulate this activity. By examining Romania's present legislation in this field referring to the quality of the metallic constructions (C150-99) one can notice the misalignment with the international norms. Moreover, the maintenance and making appeal to STASs (State Standards), irrespective of their content, compiled with SR EN (EN Romanian Standard), represents a negative technical side. The use of this mixture of norms leads to technical confusions with mistakes which cannot be repaired throughout the execution of the works.

As concerns the materials used, the current platband plates and profiles, they have the characteristics of deformation on a direction perpendicular on the surface (Z) different from those which are obtained in the plane of the surface (X). This anisotropy causes a lamellar flaking in the T welded constructions amplified by the welding method and technology. The deformation characteristics on Z direction can be improved only by additional operations in the steel-making stage. Consequently, for such welded joints it must be expressly stipulated, in the design stage, that this material should be made besides symbolizing the quality class of the added steel, also symbolizing the SR EN 10164 quality class with the mention of the Z15, Z25 or Z35 quality class.

As an example of technical seriousness from the part of a supplier in Austria in photos 1 to 8 is presented a plate with 500 thickness fixed on the foundation pillars where the T joint is submitted to a strain on Z direction. A lamellar fraying is seen on the edge, on the occasion of the ultrasonic examination of the welded joint and confirmed by magnetic particles. When the construction reached the third floor, all the executed welded joints were cut, the high strength screws were taken out and discarded, the plates were replaced with another ones of 60 and 70 mm to compensate for the loss by disassembly, the pillars edegs were processed and the execution went on with a certain delay. At present the construction looks like that one in photo (8).

The mistake came from the fact that when the order was made for the plate it was not made the symbolizing of the quality class on Z direction, but the standard (EN 10164) stipulates that if the purchaser has not made any choice, the supplier must talk with the purchaser for this matter.

From the above example one can draw the conclusion that the non-destructive examination proper has a great importance. The first method which is 100% applied of a capital importance and at the same extent partially ignored is *the visual examination (abbreviated VT).*

The visual examination should include the following stages:

a) The examination of the documentation – of the design – in order to know the constructive and functional characteristics of the construction, of the execution

order for the works and the technical conditions for their execution. In this respect I mention, from my practice, the analysis of several designs which appealed to standards which were revoked.

b) The checking of the materials correspondence with those prescribed. A apecial attention will be paid to the exactity of the existing marking and to that in the documentation in case of reception.

c) The visual examination of the surfaces before beginning the completion by welding, which consists of:
- the checking of the aspect, the form and the size of the joint and of the quality of the surfaces which are to be repaired, watching for some possible surface flaws;
- the checking of how clean the surface is, cleaning it with the wire brush, by dry polishing or other mechanical means;
- the cleaning of the surface from penetrant liquids or magnetic partticles by means of water and suitable solvents;

d) The checking of how correct the general preheating and the prescribed temperature between passes were applied, watching that the placing of the preheating means assure the correct distribution of the temperature according to the execution documentation and allow the access to perform the welding. The checking of the temperature is made on the posterior surface of the welding. The checking of the preheating temperature is made by means of thermocouples and pyrometers, preferably with recording.

e) The interphase visual examination for the execution of the weld consists of:
- the checking of the way the weld root is processed, watching the cleaning up to clean metal of the edge of the first weld row before starting again to weld on the processed part; the form and the sizes of the resulted joint must allow for the complete melting of the next row;
- the checking of the way the slag is cleaned between rows and layers, watching, especially, the joint between the deposited metal and the melting surfaces; the deposition of the next rows is made only after repairing any visible flaws;

f) The examination after welding is made when finishing the welding and after any repair operation and it consists of:
- the checking of how slag is cleaned and how the weld is joined so that no covered flaw should remain;
- when processing the surface, the polishing direction will be observed in order to avoid local overheating; the pass from the weld to the base metal will be smooth and without unevenesses;
- attention will be paid to the edge indents, the possible local burns, cracks, etc;
- after the compulsory heat treatment a new visual examination will be made.

g) In case of repairs through the welding of the welded joints one must check:
- the observance of the technology to remove the area with flaws; the removing of cracks;
- the sizes of removed area must have the edges with smooth passes so that to allow the restart of welding;
- after repair the visual examination will be made again as for the initial weld.

It is well that every stage of visual examination should contain a written text to which it is answered affirmatively or negatively for the execution and what has been found out by issuing a signed visual examination report.
The staff who does the visual examination must know the documentation, the welding procedure, must have a good sight (periodically checked every 12 months) and must be trained (qualified) by care of the employer to the specific of the activity which he performs.

Another non-destructive method is the examination with *magnetic particles (abbreviated MT)* which is the best method to determine the surface cracks. The method is based on the appearance of some dispersion magnetic fields on the magnetized surface in the areas where there are material discontinuities. The dispersion magnetic fields are located on the surface by the agglomeration of fine magnetic particles distributed on the surface. The agglomeration of magnetic particles will indicate the location of the discontinuity, the size as regards the length and the form of the discontinuity on the surface. It does not present any information on the depth.

The *ultrasonic examination (abbreviated UT)* is applied when measuring material thicknesses and determining the inside discontinuities, as concerns the size of the position in the welded joints, when determining the peeling/exfoliation in plates.

The determination of the size of discontinuities by means of ultrasounds is at present *real, exact, reproducible and cheap.* The discontinuities are simulated through reflectors under the form of cylindrical holes, U, V or semicircular channels, whose dimensions are established in norms, procedures and discussed when contracting.

The method with the reference blocks assures a *high reproducibility* and associated with the technological evolution of microprocessors allows the *computer recording* of the results.

The appreciation of discontinuities by means of the reference blocks consists of tracing on the (electronic) screen of the allowance curves placed as agreed when contracting. These curves are at values which have a difference among them of 6 dB. Three or four curves can be traced automatically on the screen see table 1

An interpretation example is shown in the table below and which is indicated in photo 9.

Table 1

C1 curve (-12 dB)	C2 curve (-6 dB)	C3 curve (reference)	C4 curve (+6 dB)
The indications under this curve are acceptable	The indications between C1 and C2 are recorded and are accepted	The indications between C2 and C3 are accepted if the length is max 1/3s	The indications between C3 and C4 are acceptable if they are local and with the enduser's agreement

The raising of curves is made on the calibration block which corresponds to the welded joint which is inspected.

The ultrasonic device has been manufactured, for a long time (almost 20 years), with microprocessors which allow the programming in different working fields, the computer recording of results, the obtaining of multiple reproducible information, eliminating the human errors, in a very short time. The staff who apply this method will have to be qualified, certified, having a period of experience in the field.

The *liquid examination (abbreviated RP)* consists in the application on the surface of a fluid susbstance which is called penetrant liquid and which penetrates into discontinuities. The excess of the liquid in the discontinuity is removed and another substance which absorbs the liquid in the discontinuity is applied on the surface, highlighting in this way the length and the form of the discontinuity with the exception of its depth. The method is applied to highlight only the discontinuities open at the surface of the metallic materials, the welded joints and repairs through welding such as cracks, pores, exfoliations, cavities, ridges, overlaps, lack of fusion etc., only if they have open access to the surface. The method is easy to apply it implies a certain range of temperatures with conscientiousness from the part of the staff who apply it. This method is more expensive and it requires a longer period of working time as compared with the magnetic particle examination.

The *radiographic examination (abbreviated RP)* is based on the fact that when the X or gamma radiations penetrate a material, they are more or less absorbed and it highlights the variations of the density/composition. The decision is obtained by interpreting and evaluating (total or partial recognition) the information. The advantage consists of the fact that the results can be visualized on a film, as concerns the size and the form, through projection. It highlights volume internal discontinuities and it has many applications at the examination of butt welded joints. As a technical disadvantage is the fact that it cannot establish in the section the position of a discontinuity or better to say on which surface to make the repair in order to have a maximum efficiency. The method is limited from the physical point of view, because it uses equipment which emits dangerous radiation and economically it is the most expensive method.

All these methods complete reciprocally in certain fields, each one having an optimum on a certain area. All of them have known a technological evolution connected with: the application field, the electronic equipment and the microprocessor technique which is in an exponential evolution.

4. Conclusions

- The construction works must be made having as a basis *the designing based on performance, assisted by microprocessors.*

- The updating and the *adoption* by the authority in the field "The State Inspectorate for Constructions" of the European *norms "Eurocode"*.

- The certification of the staff in the *visual non-destructive* examinations *(VT)* taking into consideration that it represents at present the greatest drawback, the responsibility is totally to the employer who issues the quality certificate.

- The execution of the welded joints is *made on basis of procedures* issued by certified staff and by qualified and specially trained welders for the procedure which they apply.-
- An increased exigency in the field of *the technical supervision of constructions*.

References

1. ASNT Nondestructive Testing Handbook Ultrasonic Testing, 1991.
2. T. Bohatiel, Physical and Technical Non-destructive Examination, Technical Printing House, 1980.
3. J. Krautkramer , Ultrasonic Testing of Materials, Berlin, 1990.
4. D.R. Mocanu, Testing of Materials, Vol.3, the Technical Printing House, 1985, Bucharest.
5. E. Nastase, Ultrasonic Examination of Weld Joint, Ghent University, Belgium, 2000.
6. Standard concerning the quality of the steel welded joints in the civil, industrial and agricultural constructions, indicative C 150-99.
7. STAVELEY SONIC 1200 Olympus Ultrasonic Device, Operation Manual, 1999.

Photo 1

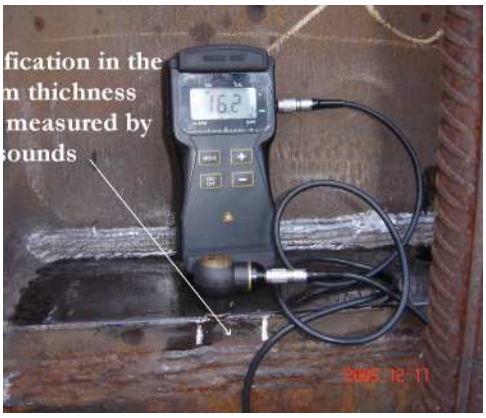

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

Photo 8

Photo9