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ACOUSTIC EMISSION ON STRESSED CONCRETE

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ABSTRACT :

In a first part of this study, a comparison is made between the mechanical behaviour and the acoustic emission measurements on laboratory specimen during four points bending tests. The specimen were made of plain or/and reinforced concrete.

The second part confirms, on reinforced beams 3,5 m long, the laboratory study results.

1. INTRODUCTION*

Safety of concrete structure involves the possibility of their inspection in service or by overload testing. For this reason, it has been considered to use acoustic emission during cracking as a method to detect damages in a structure.

Before such a method can be used on actual structures, it is necessary to study in laboratory some mechanical elementary cases. For this reason, the study has been divided into two parts :

. caracterisation in laboratory of acoustic emission during fracture in four points bending tests on non reinforced and reinforced beams (10 x 10 x 50 cm).

. passing to full size test with four points bending test on beams (3,50 m bearing and 15 x 30 cm section).

In these two cases, the strains and the acoustic emission parameters have been simultaneously measured so that to establish relations between some parameters of acoustic emission (number of events and amplitude) and mechanical parameters for the different phasis of the material behaviour.

2. CARACTERISATION IN LABORATORY

2.1. Définition of the test

Every laboratory test has been realized with a kind of concrete representative of usual industrial mixes, on a servo-hydraulic machine, which allows to control propagation of cracks in order to observe with precision the different phasis or the destroying sample.

In acoustic emission measurements, a particular care has been taken to obtain a good signal to noise ratio and to insulate acoustically the specimen from the testing machine.

2.2. Bending test on non reinforced beams (10 x 10 x 50 cm)

2.2.1. Experimental conditions

The loading apparatus was designed in order to meet the following requirements :

- possibility of tangential displacement of the sample at the loading points,
- reduction of contact stresses,
- minimization of local stresses due to the surface defects of the specimen.

* This study has been realized thanks to a DGRST contract between CEBTP and CEA.

Each test has been conducted with a constant displacement rate (0,05 mm/mn).

The specimen was notched in its central part in order to propagate a single macrocrack.

The bending of the beam and the opening of the notch have been measured during the tests. Previous tests have been done to be sure that all the events detected are really coming from the sample and not from the loading device.

2.2.2. Results

Figure 1 shows a typical force-deflection curve. The behaviour of the specimen is linear up to the deflection F_E. From F_E to the deflection F_M corresponding to maximum force the behaviour becomes non linear. After F_M has been reached, the force decreases with increasing deflection. Propagation of a single macrocrack becomes visible during this last phase.

The same conclusions can be drawn when considering the notch opening measurements.
Acoustic emission appears from the deflection F_E, corresponding to the end of linearity and the Amplitude-distribution analysis shows that events generated between the end of linearity and the maximum stress are exclusivly low amplitude events (< 0,5 V) ; higher amplitude events (> 0,5 V) are only created beyond the maximum load, just when macrocrack begins to propagate (figure 2).

Concluding the previous results, the following remarks can be made :

- sample microcracking generates low amplitude events, so that acoustic emission is a way to detect the first damages within the concrete ;
- higher amplitude signals appear at the beginning of the macrocracking, while cracks are still not visible on the sample,
- the amplitude distribution is reproductible from one sample to another.

2.3. Bending tests on reinforced beams (10 x 10 x 50 cm)

2.3.1. Experimental conditions

Loading machine used and crack opening displacement transducer are the same as previously ; the controling parameter is also the actuator displacement : 0,40 mm/mn. Concerning acoustic emission detection and loading apparatus noise, the setting is the same as previously.

2.3.2. Results

Figure 3 shows a typical force-deflection curve :

- before deflection F_E, the behaviour is linear, no macrocrack forms within the specimen,
- between F_E and F_P, cracks form in the lower part of the specimen. The reinforcing steels are still elastic,
- after F_P, the steel is deformed plastically. The maximum load is reached for a deflection F_M.

Only the beginning of the curve, the most important part for nondestructive testing, is ploted on the figure 4 :

- first events have been detected, from a deflection of about 20 µm (approximatively the linear limit F_E) and have exclusively low amplitude : the mechanical parameter are in the microcracking range ;
- higher amplitude events (> 0,5 V) only appear from F_E, deflection corresponding to the beginning of propagation of cracks, which are not yet visible on the sample ;
- the normalized amplitude distribution is the same from one sample to another and is constant between F_E and F_P : once created, cracks go on propagating until the total destruction of the sample.

3. BENDING TESTS ON FULL SIZE BEAMS (15 X 30 CM SECTION, 1,50 M LENGTH)

The aim of those tests is to extend the elementary specimens results to representative building elements, made of course, of the same concrete.

3.1. Experimental conditions

Flexure test is a four points bending one, with special arrangement at the loading points to avoid unwanted acoustic emission.

The loading is regulated at a constant speed of increasing deflection.

3.2. Results

Acoustic emission becomes significant from the load of 5 kN, corresponding to the deflection F_E. The amplitude distribution is the same from a beam to another and stays constant from F_E to F_P. This distribution is associated with propagation or cracks and is not affected by the plastic deformation of steel (figure 5).

The amplitude distribution is the same as for propagation of cracks in reinforced beams.

At last on the figure 6, the rise of number of counts, before ultimate load appears very clearly. This fact has already been observed on the laboratory specimen.

4. DISCUSSION AND CONCLUSION

On the laboratory specimens submitted to simple process of four points bending loading, it has been observed, the first damages are associated with microcracking : acoustic emission is a privileged way to detect the first microcracks in concrete.

The amplitude analysis shows that amplitude of the events increases with dammages and a particular amplitude distribution can be associated to the propagation of cracks ; the nature and importance of the dammages created in the material can be estimated.

On real reinforced beams, four points bending tested, acoustic emission gives the identification and the approach of rupture, as other extensometric methods.

Moreover, amplitude analysis allows to indentify the state of damage by giving the beginning of the yield cracked phasis. This result is important, from a non destructive point of view of civil engineering, because it can give a useful diagnosis, in a state of loading, which generally corresponds to the working stress of structures.

- FIGURES PANEL -

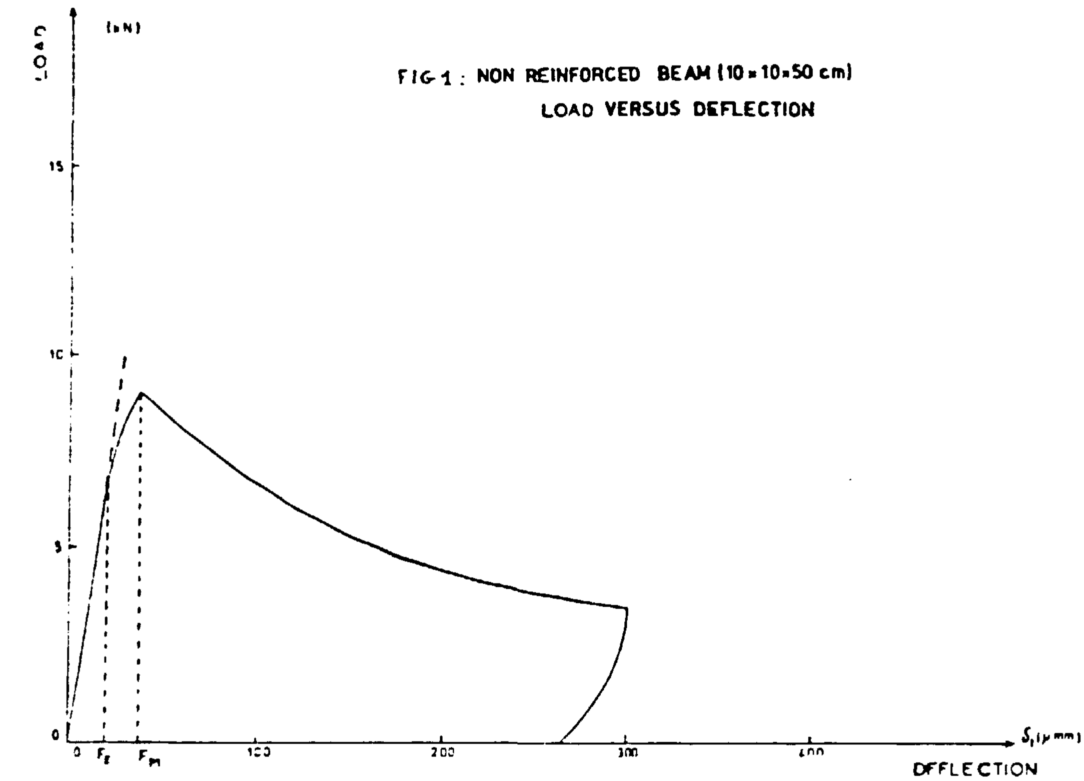


FIG 1 : NON REINFORCED BEAM (10 x 10 x 50 cm)
LOAD VERSUS DEFLECTION

FIGURE 2 : NON REINFORCED BEAM (10 x 10 x 50 cm)
AMPLITUDE DISTRIBUTION OF ACOUSTIC EMISSION VERSUS DEFLECTION

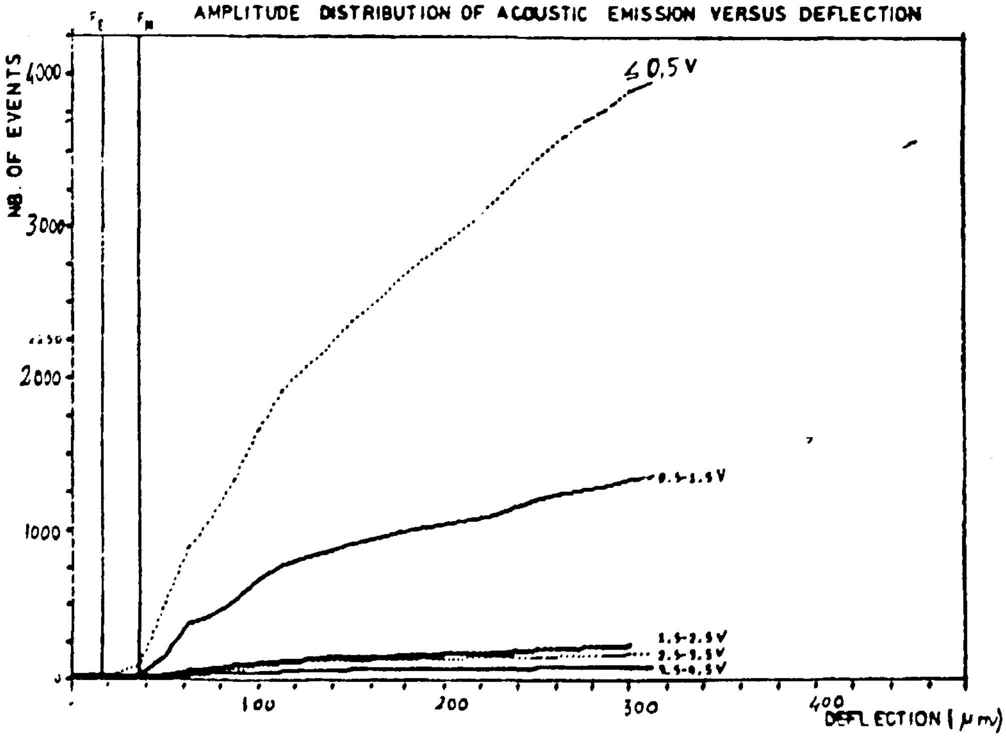


FIG 3: REINFORCED BEAM (10×10×50 cm)
LOAD VERSUS DEFLECTION

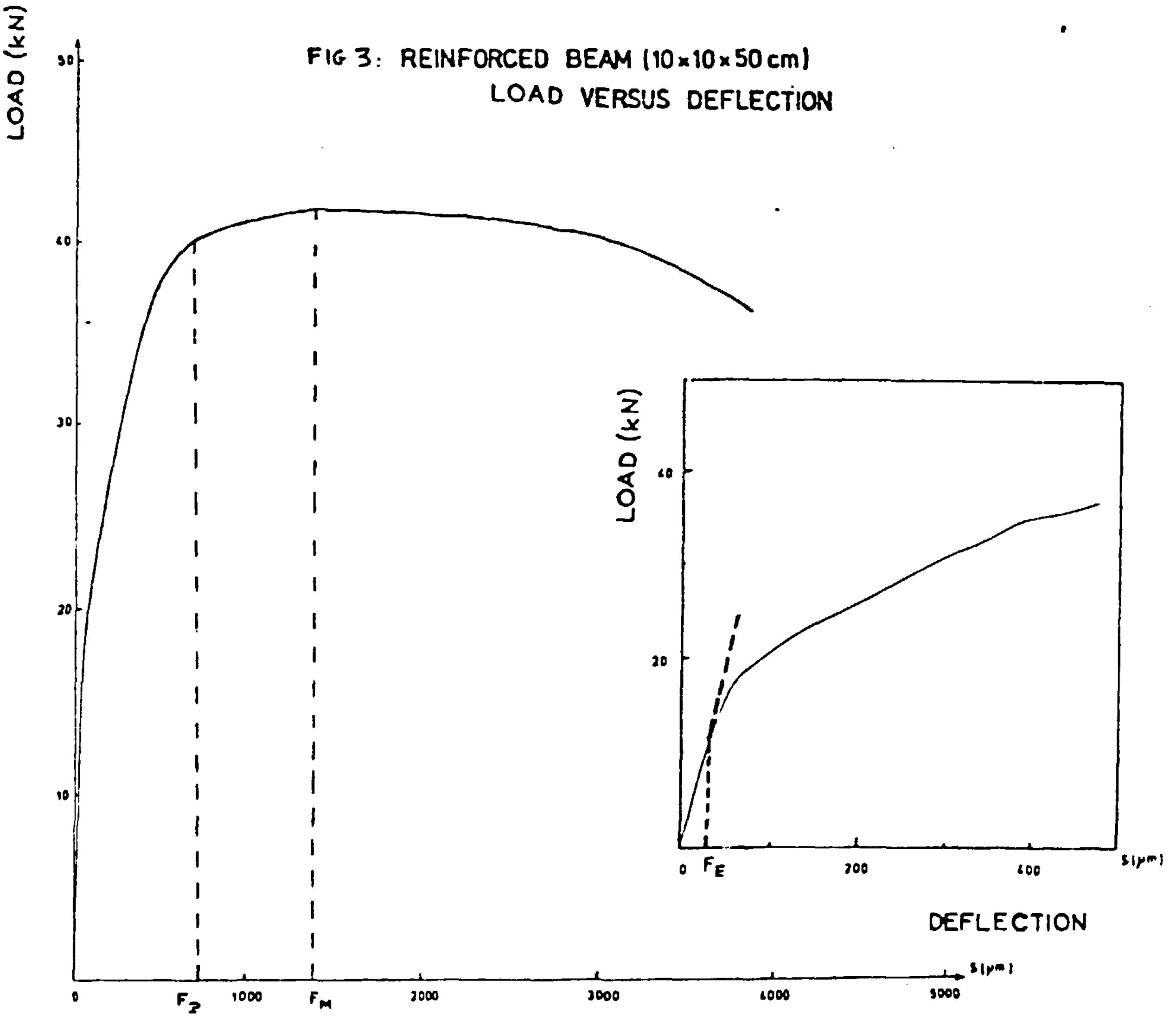


FIG. 4 REINFORCED BEAM (10×10×50 cm) N° 26
AMPLITUDE DISTRIBUTION OF ACOUSTIC EMISSION VERSUS DEFLECTION

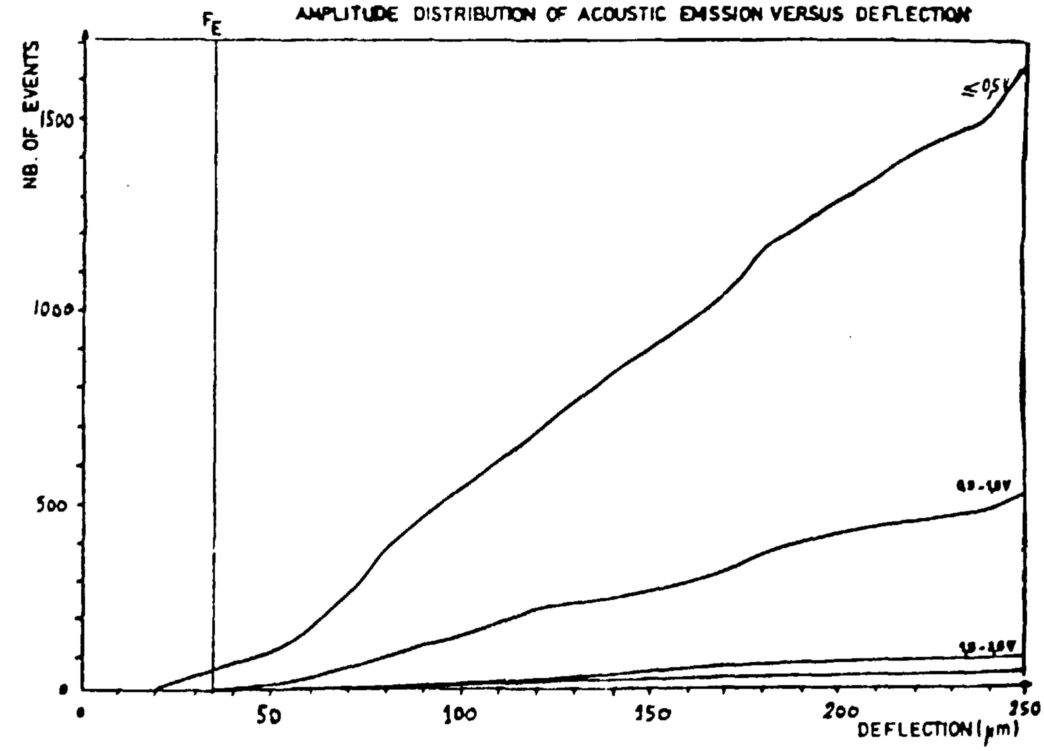
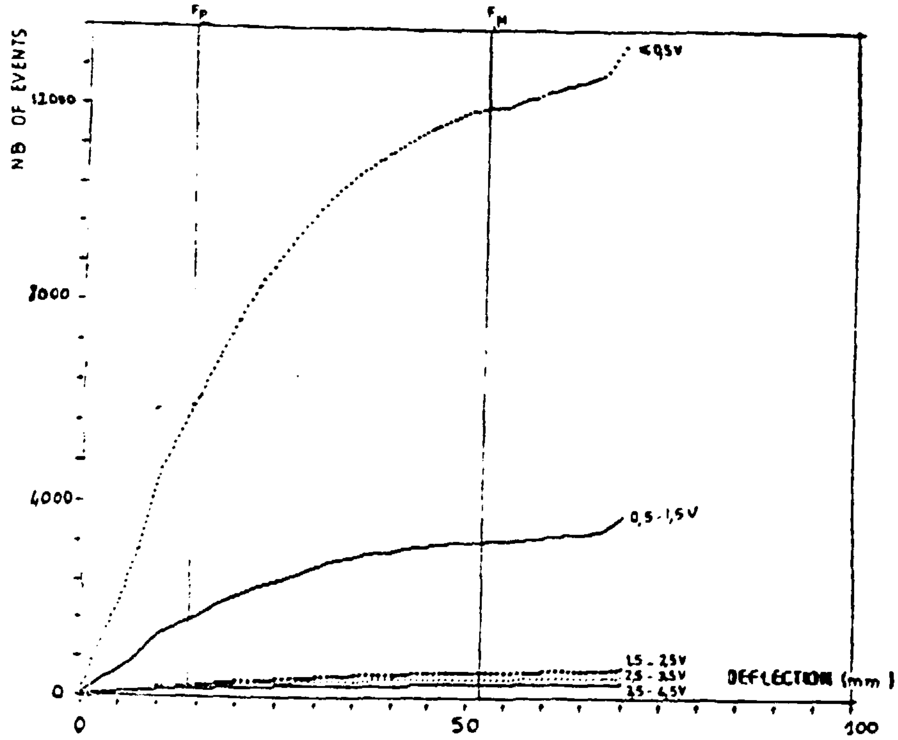


Fig 5 . AMPLITUDE DISTRIBUTION OF ACOUSTIC EMISSION VERSUS DEFLECTION



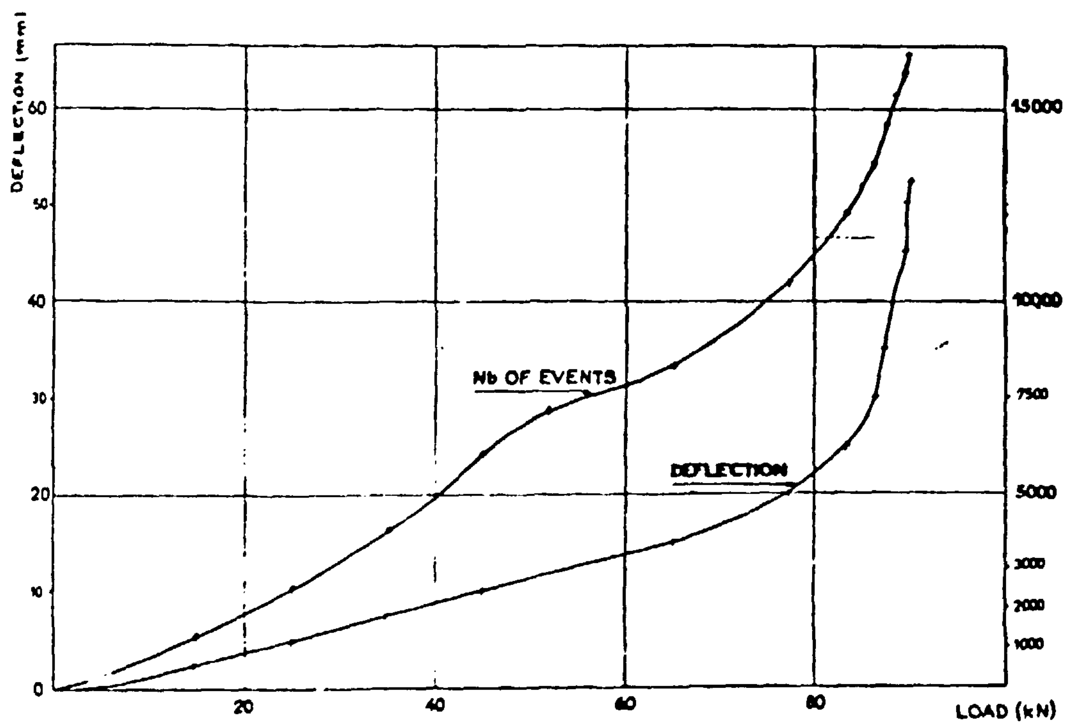


FIG 6 . CUMULATIVE ACOUSTIC EMISSION AND DEFLECTION VERSUS LOAD