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Project Suspension

Development of Silt Measuring Methods

Acoustic attenuation during salt flocculation of fine sediment particles

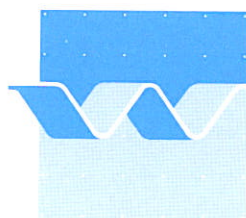
Progress Report

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Development of Silt Measuring Methods

Acoustic attenuation during salt flocculation of fine sediment particles

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delft hydraulics

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FIGURES

1 Introduction

Flocculation measurements have been carried out in salt water with China Clay and Eems-Dollard silt.

China Clay and Eems-Dollard silt suspensions were pumped around through a vertical tube with a diameter of 10 cm.

The start of the flocculation process corresponded with the moment the pump was closed down. The flocculation process took place in a salt water column at rest. The length of the water column was 240 cm.

During flocculation acoustic attenuation measurements were carried out at a number of frequencies between 1 and 100 MHz.

An optical attenuation measurement has been done during an experiment with China Clay. The light source was a He-Ne-laser.

During flocculation flocs are growing to aggregates of 100, may be 200 μm diameter. The light attenuation of a China Clay suspension is mostly determined by the concentration of fine unflocculated particles rather than by the bigger flocs. Therefore the presence of growing flocs can be detected by means of light attenuation measurements and an estimation of flocs concentration can be made.

Figure 1.1 shows the acoustic attenuation as a function of frequency for sand of 100 μm and China Clay. There is a rather big difference between both spectra.

As flocculation proceeds the concentration of flocs increases, while at the same time the concentration of unflocculated China Clay is decreasing. If flocs behave like rigid particles, like for instance sand particles, then during flocculation a change of the frequency spectrum would be expected. The attenuation in the lower frequency region (10 - 40 MHz) would increase while the attenuation in the higher region (70 - 100 MHz) would decrease.

2 Preparation of flocculation measurements

A complete description of the experimental set-up such as the circuit, the acoustic and optical measuring sections is given in [1].

The preparation is started by filling the circuit with clean saltwater with a density 1025 kg/m^3 (density of seawater).

The temperature control was adjusted in such a way that the temperature changes during flocculation would be as small as possible. The maximum temperature change during the experiments was less than $0.05 \text{ }^\circ\text{C}$.

After the adjusted temperature was reached an acoustic and optical reference measurement in clean salt water was carried out.

Next a certain quantity of ChinaClay or Eems-Dollard silt was put into the circuit and was pumped around during 15 minutes in order to get a homogeneous and unflocculated suspension.

After 15 minutes of pumping around, the first measurement was done. This was the unflocculated $t=0$ measurement.

After the $t=0$ measurement, the pump and the temperature control, which only works when the circuit is in action, were switched off. By stopping the pump the flocculation process was started.

3 Flocculation measurements

The following series of experiments, during which the flocculation was studied by means of acoustic and/or optical attenuation measurements, have been carried out:

Experiment	Sediment	Concentration	Kind of Measurement
1	China Clay	0.60 kg/m ³	Acoustic and Optic.
2	China Clay	1.50 kg/m ³	Acoustic
3	Eems-Dollard Silt	0.60 kg/m ³	Acoustic
4	Eems-Dollard Silt	1.50 kg/m ³	Acoustic

3.1 Optical attenuation measurement

During experiment 1 (China Clay; 0.6 kg/m³) every 5 or 10 minutes the optical attenuation in the centre of the column was measured over an optical pathlength of 15 mm.

At the same time the concentration in the column, at the same level as the optical measuring section, was measured by taking 100 ml samples with a small suction tube.

In figure 3.1 the relative attenuation as a function of time is given for times between 0 and 60 minutes.

The straight line in the figure is the calibration of the optical system for unflocculated China Clay.

3.2 Acoustic attenuation measurements

During the flocculation process the acoustic attenuation at thirteen frequencies between 1 and 100 MHz has been measured every five minutes.

A single measurement at one frequency takes about 14 seconds, so a complete, but low resolution, spectrum could be measured in about 3 minutes.

The attenuation spectra at different points in time of the flocculation process, have been drawn, for each of the four experiments, in the figures 3.2, 3.4, 3.6 and 3.8.

The attenuation as a function of time for the different frequencies is shown in the figures 3.3, 3.5, 3.7 and 3.9.

The concentration nearby the acoustic measuring section is measured during flocculation by taking 100 ml samples.

The relative concentration ($C/C(t=0)$) as a function of time is also given in the figures 3.3, 3.5, 3.7 and 3.9.

4 Results and discussions

4.1 Optical results

In figure 3.1 the light attenuation as a function of concentration is shown. The data-points in the figure have been measured every 5 or 10 minutes during flocculation.

The figure shows an initial rise during which the concentration remains constant and the light attenuation decreases.

The reduction of the light attenuation is caused by the formation of flocs and at the same time a reduction of the concentration of unflocculated China Clay.

If the assumption is made that only the unflocculated China Clay contributes to the light attenuation and not the bigger flocs, then from figure 3.1 the concentration of flocculated and unflocculated China Clay can be estimated.

The results of such calculations are given in figure 4.1.

From figure 4.1 it seems that after about 30 minutes the maximum concentration of flocs is reached. The concentration of flocs then reaches 1/3 of the original unflocculated concentration, while the concentration unflocculated China Clay has been reduced with over 1/3.

After about 30 minutes the concentration of flocs reduces as a result of the settling of the flocs and the limited length of the column.

4.2 Acoustic results

The concentration nearby the acoustic measuring section as a function of time is given for each experiment in the figures 3.3, 3.5, 3.7 and 3.9. All these figures show a reduction of concentration after a certain time due to the settling of the flocs.

All measured acoustic attenuations as shown in the figures 3.2 up to 3.9 have been linearly corrected for the reduction of the concentration, in order to achieve normalized spectra at constant concentration. The constant concentration was taken equal to that at $t=0$.

From the results of the light attenuation measurements, as given in figure 4.1, an estimation of the concentration of flocculated and unflocculated China Clay can be made. After a flocculation time of about 30 minutes the China Clay suspension is composed of a mixture of unflocculated and flocculated China Clay in the mass concentration ratio of 1.5 to 1. If the assumption is made that flocs of clay or silt behave like rigid particles, like sand particles, then the influence of flocculation on the attenuation-frequency spectrum can be estimated.

From the data of figure 1.1 (attenuation of 100 μm sand and China Clay) and the estimated maximum concentration of flocs the increase and decrease of the attenuation at different frequencies can be calculated.

The attenuation frequency spectra for two points in time are repeated in the figures 4.2 and 4.3.

The first point of time $t=0$ min is the unflocculated situation, the second point of time $t=20$ or 30 min is the estimated moment of maximum concentration of flocculated sediment.

In figure 4.2 dashed lines show the attenuation spectra of mixtures of China Clay and 100 μm sand in the mass concentration ratio of 1.5 to 1. These spectra have been calculated from the data of figure 1.1.

The dashed lines show the effect if part of the mass of unflocculated China Clay has been replaced by an equivalent mass of 100 μm sand. The same effect should occur after a certain time of flocculation if flocs could be considered as solid particles like sand particles.

It is clear that such effects do not occur. The flocs have such a loose structure that they may not be compared with solid particles.

The concentration as a function of time of the Eems-Dollard silt shows a drop somewhat earlier than China Clay does. So it seems that Eems-Dollard silt flocculate more violent (greater settling velocity, bigger flocs) than China Clay. Therefore somewhat bigger effects on the changes of the acoustic attenuation of Eems-Dollard silt might be expected.

5 Conclusions

Figures 4.2 and 4.3 show the acoustic attenuation spectrum of the unflocculated situation at $t=0$ min and the attenuation spectrum of maximum concentration of flocculated sediment at $t=20$ or 30 min.

The difference between the two successive spectra is small, for all four cases. Therefore, in contrast with optical attenuation, the measured acoustic attenuation is largely independent of the degree of flocculation of the sediment.

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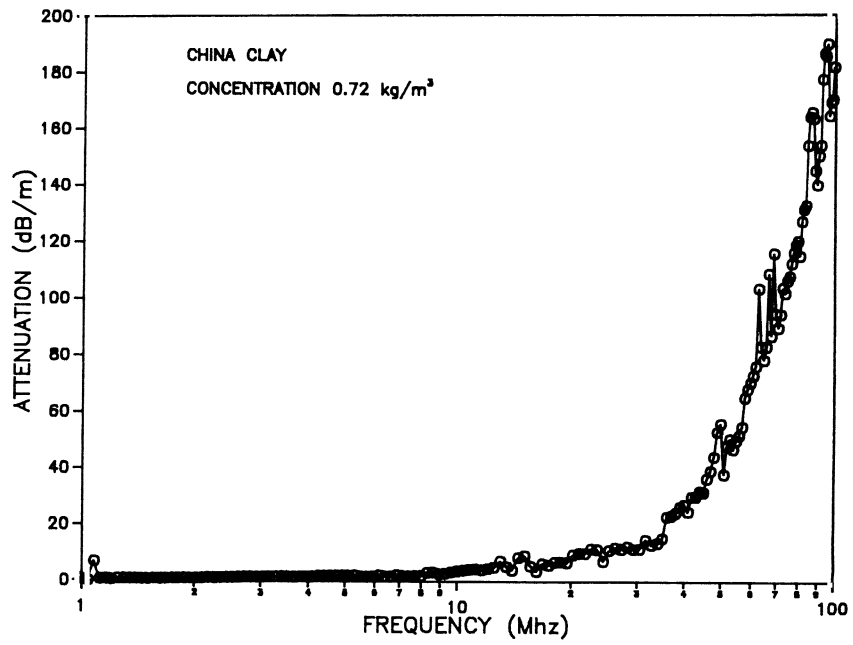
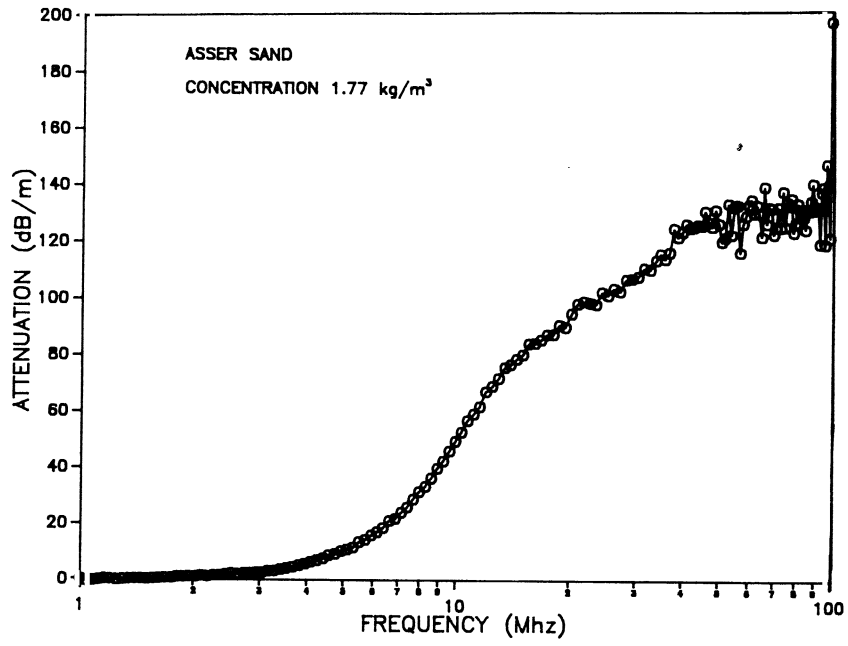


Fig. 1.1 Acoustic attenuation for Asser Sand (sieve size fraction 90–100 μm) and China Clay.

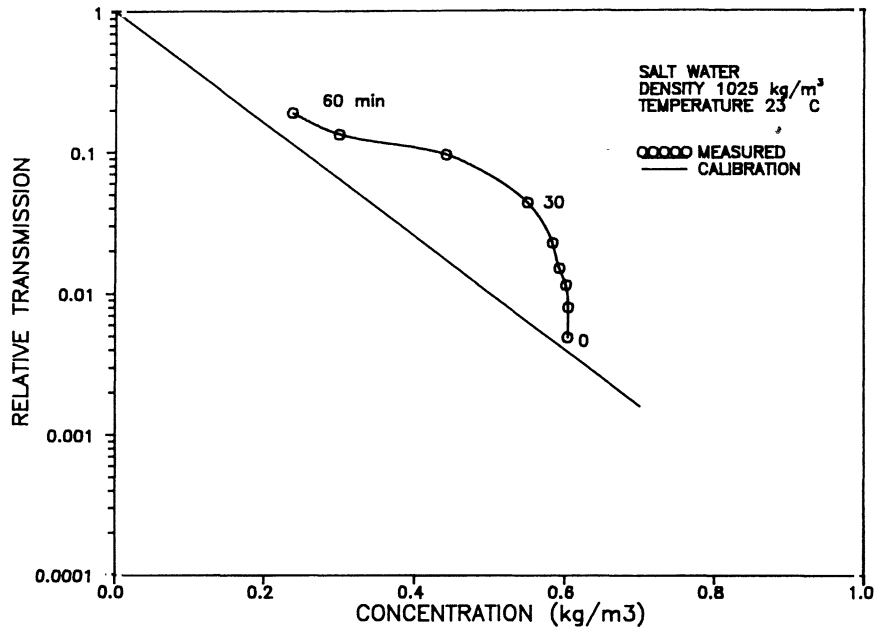


Fig. 3.1 Relative light attenuation as a function of China Clay concentration at certain points of time during flocculation

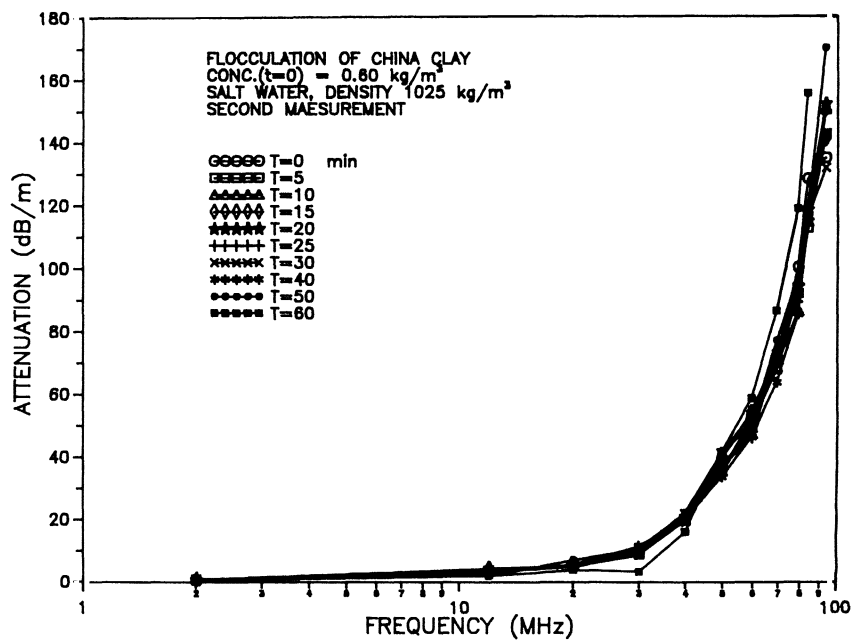
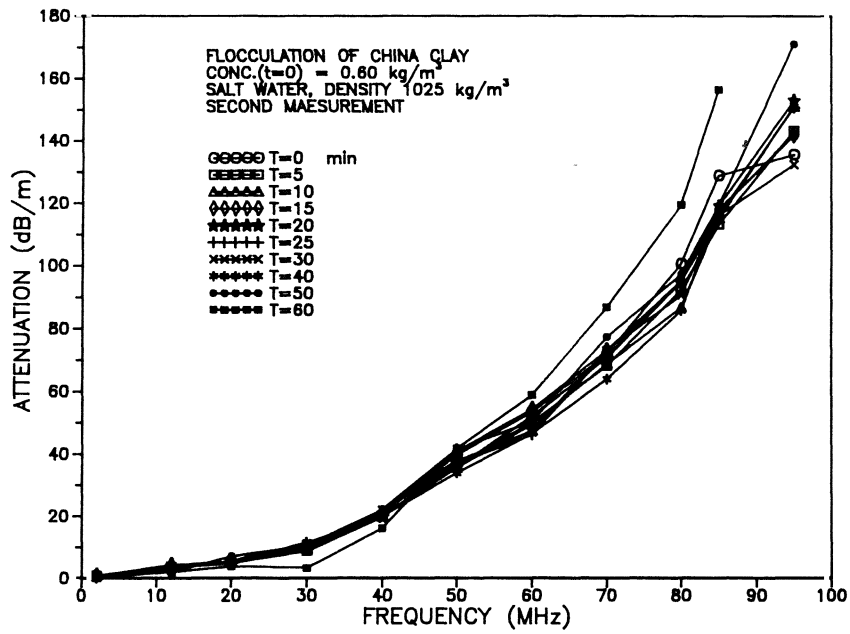


Fig. 3.2 Normalized acoustic attenuation spectra of a China Clay suspension, Conc.(t=0)=0.6 kg/m³, during flocculation. Linear and logarithmic frequency scale.

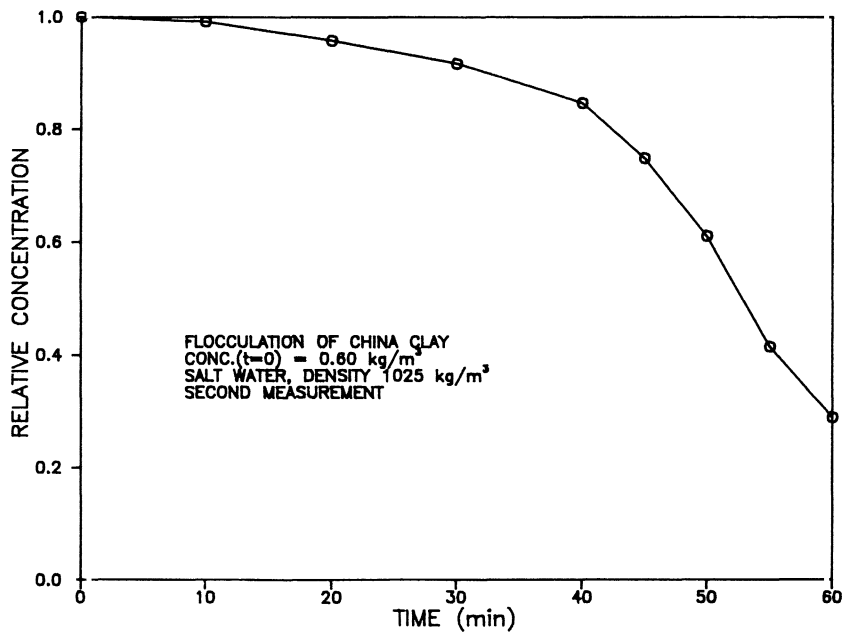
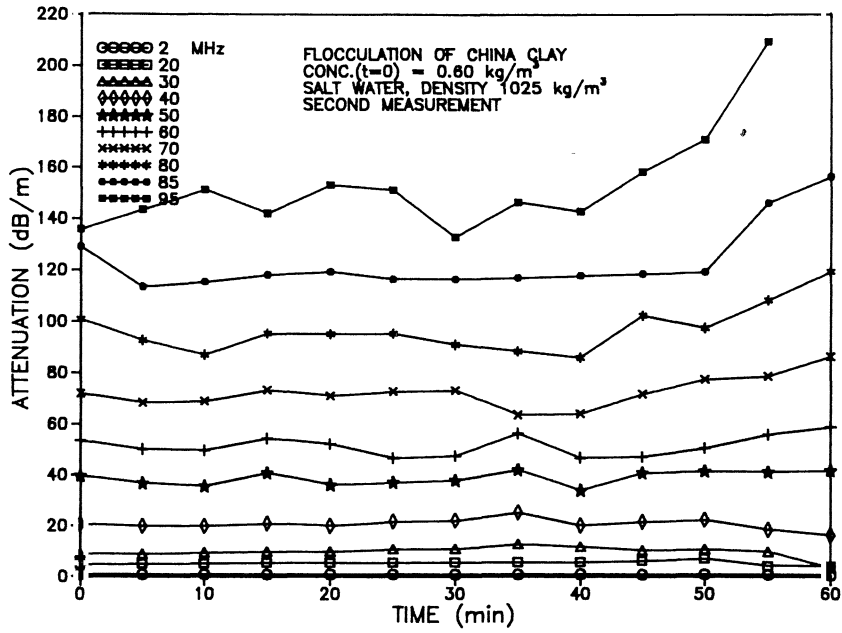


Fig. 3.3 Normalized acoustic attenuation and relative concentration as a function of time during flocculation of a China Clay suspension, Conc.(t=0)=0.6 kg/m³.

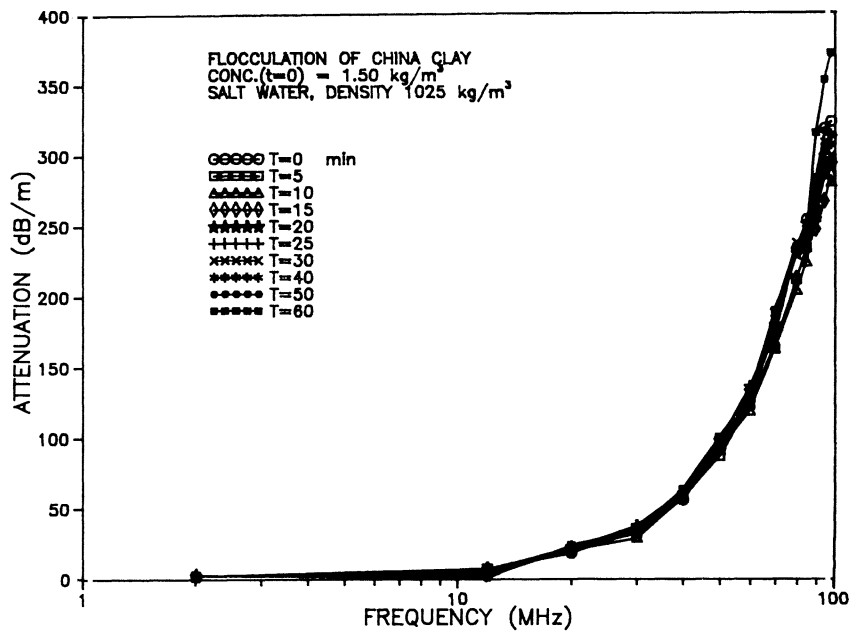
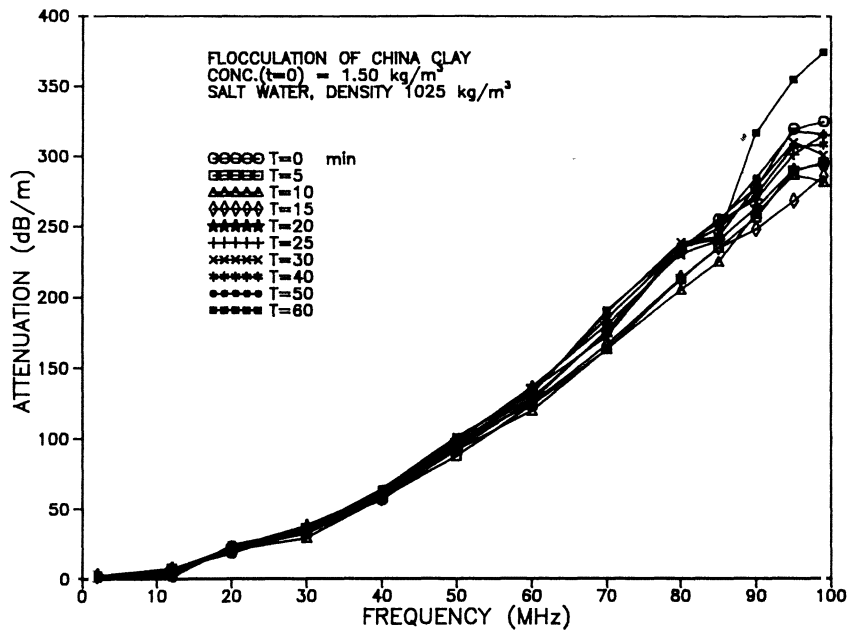


Fig. 3.4 Normalized acoustic attenuation spectra of a China clay suspension, Conc.(t=0)=1.5 kg/m³, during flocculation. Linear and logarithmic frequency scale.

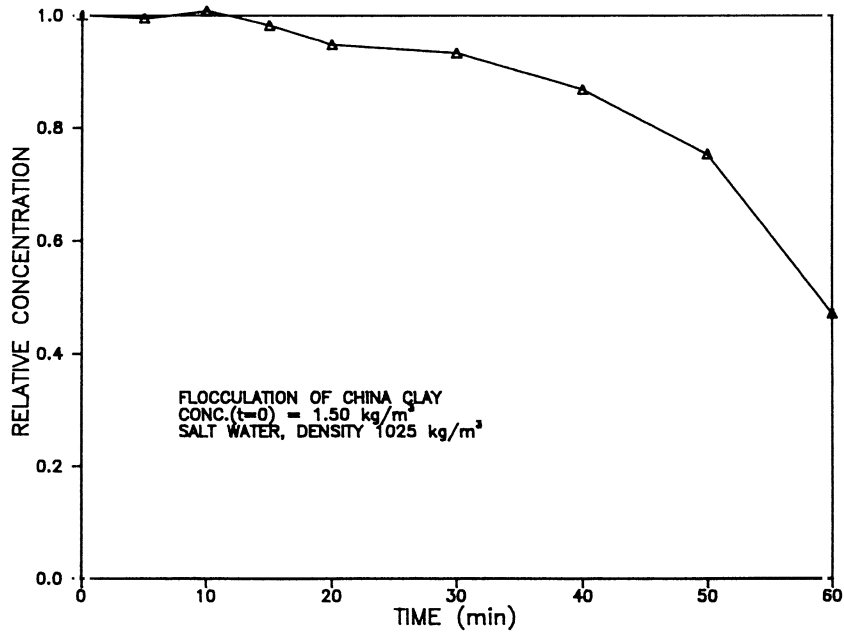
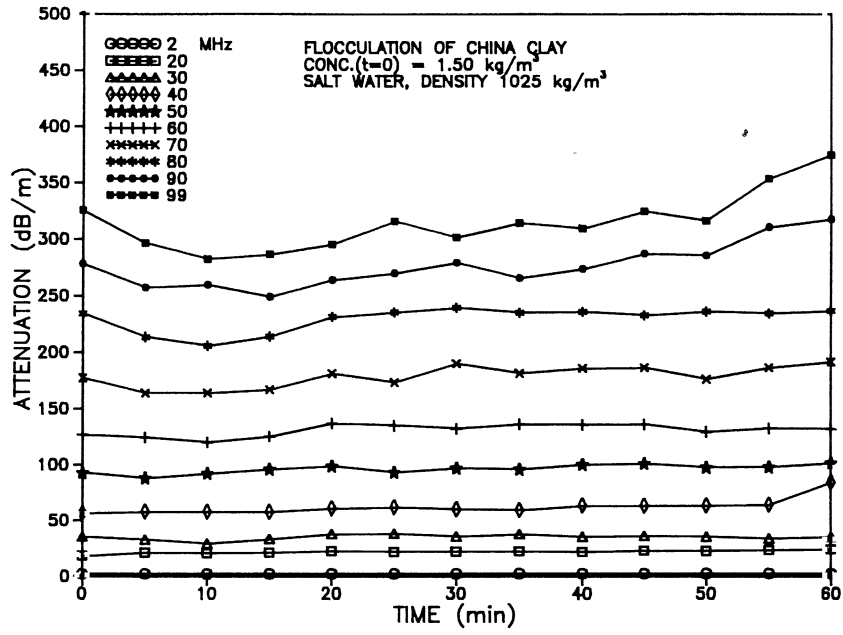


Fig. 3.5 Normalized acoustic attenuation and relative concentration as a function of time during flocculation of a China Clay suspension, Conc(t=0)=1.5 kg/m³.

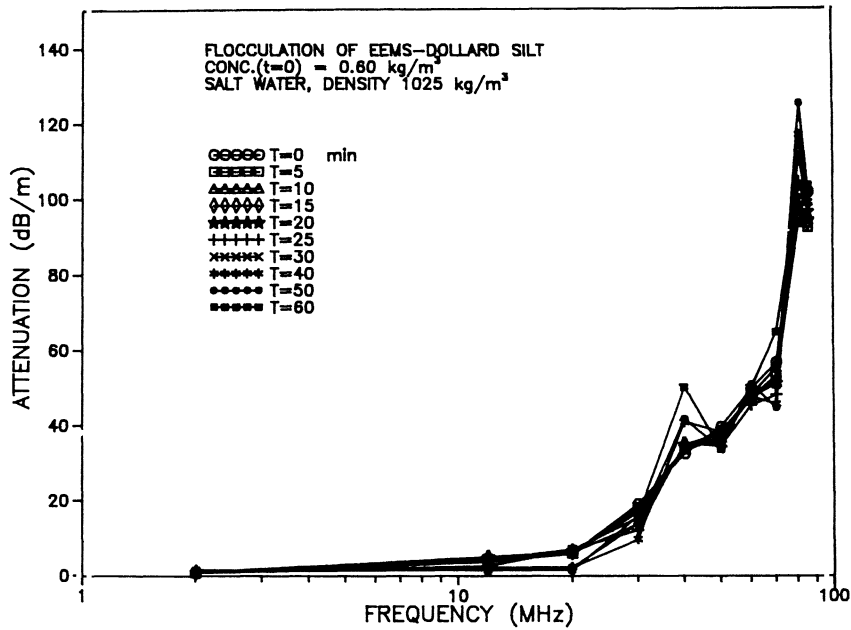
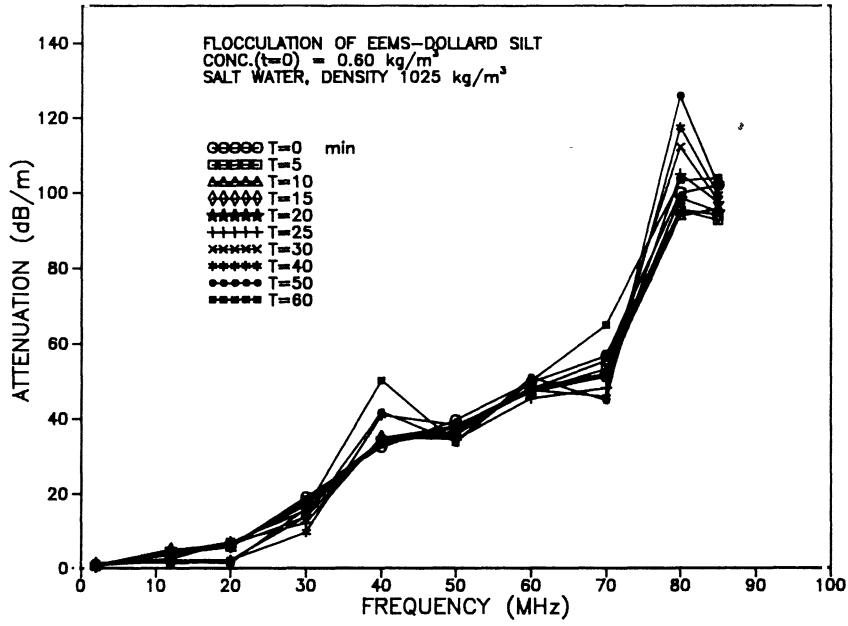


Fig. 3.6 Normalized acoustic attenuation spectra of Eems-Dollard silt suspension, Conc.(t=0)=0.6 kg/m³, during flocculation. Linear and logarithmic frequency scale.

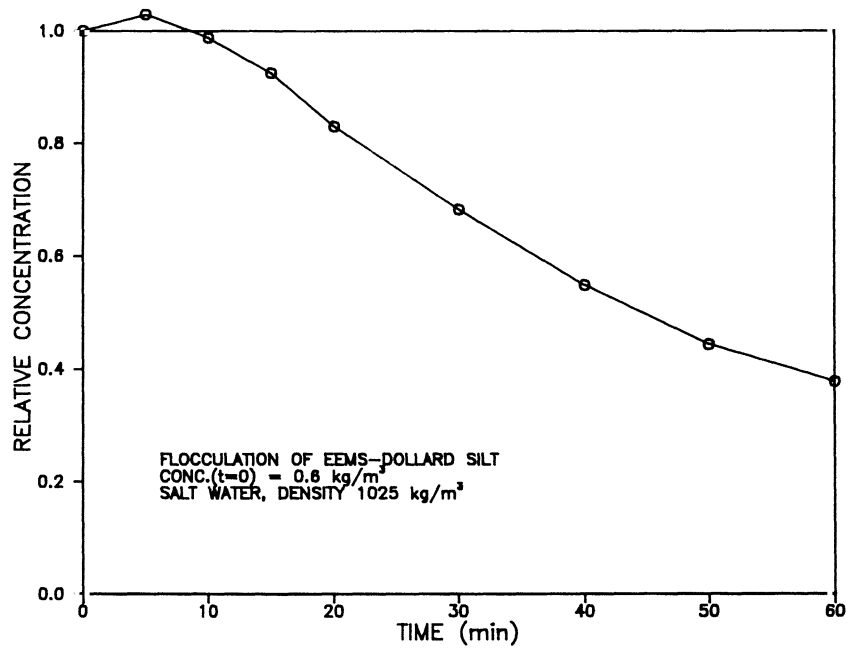
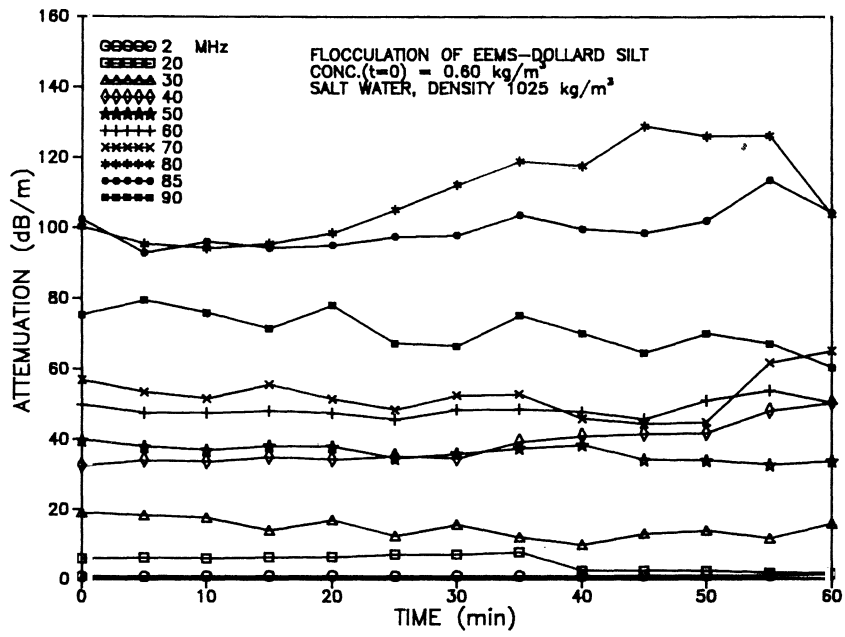


Fig. 3.7 Normalized acoustic attenuation and relative concentration as a function of time during flocculation of a Eems-Dollard silt suspension, Conc.(t=0)=0.6 kg/m³.

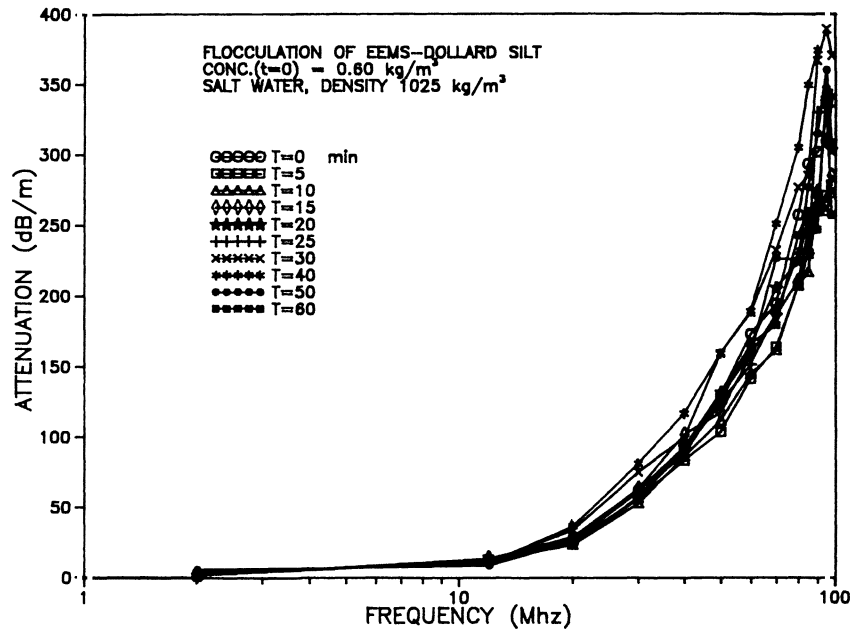
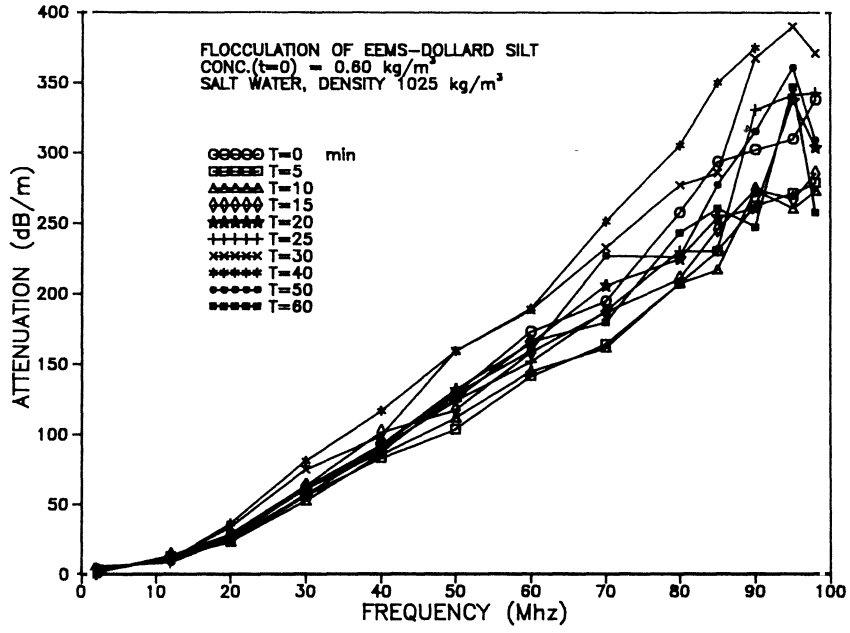


Fig. 3.8 Normalized acoustic attenuation spectra of Eems-Dollard silt suspension, Conc.(t=0)=1.5 kg/m³, during flocculation. Linear and logarithmic frequency scale.

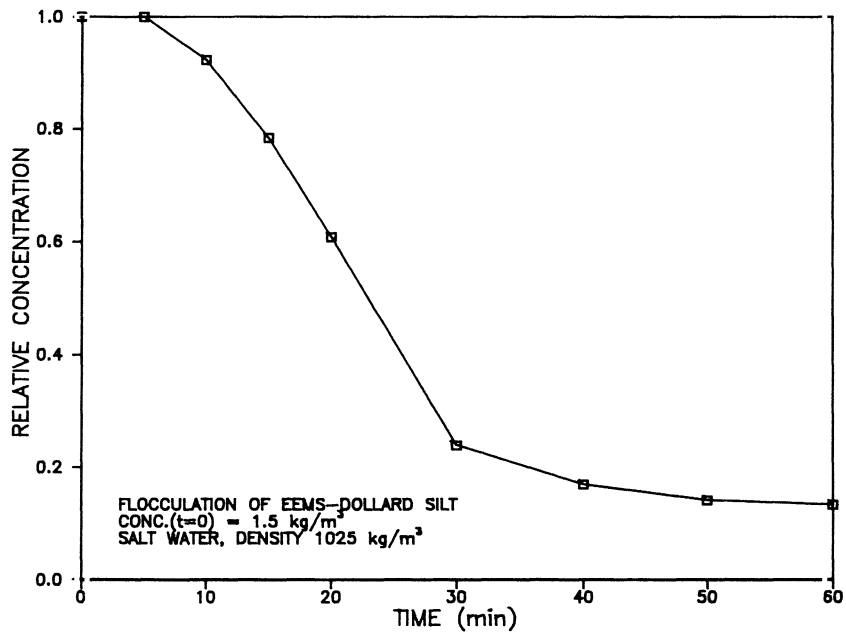
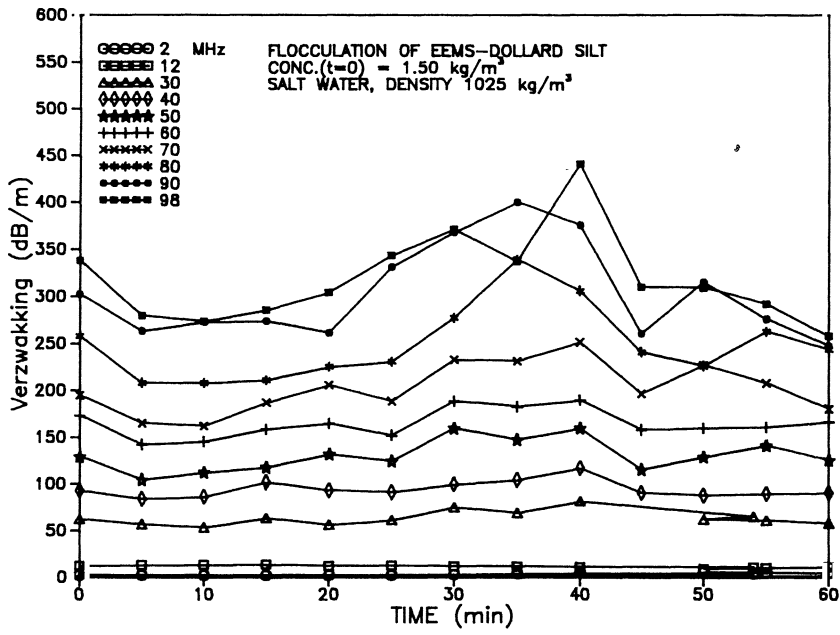


Fig. 3.9 Normalized acoustic attenuation and relative concentration as a function of time during flocculation of a Eems-Dollard silt suspension, Conc.(t=0)=1.5 kg/m³.

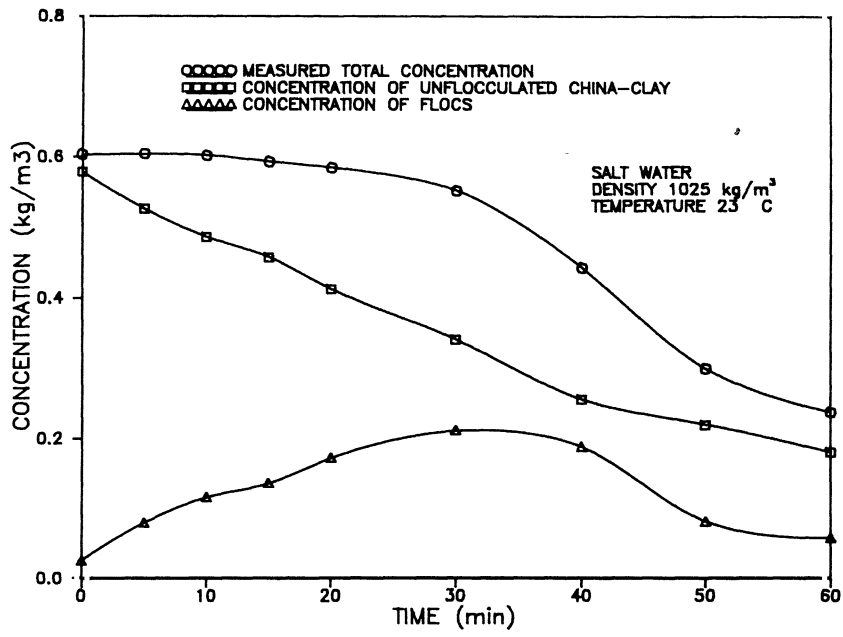


Fig. 4.1 Estimated composition of a China Clay suspension, Conc.(t=0)=0.6 kg/m³, as the flocculation process proceeds.

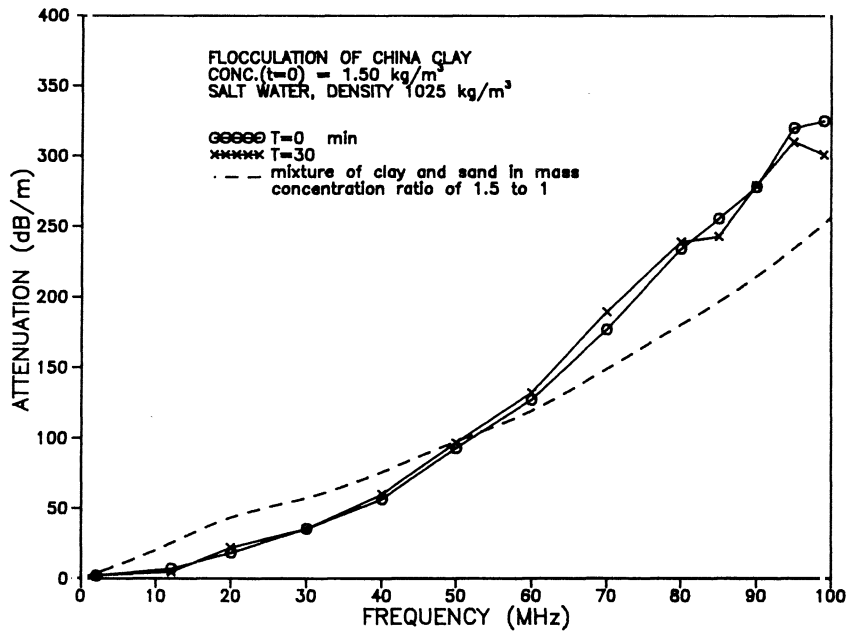
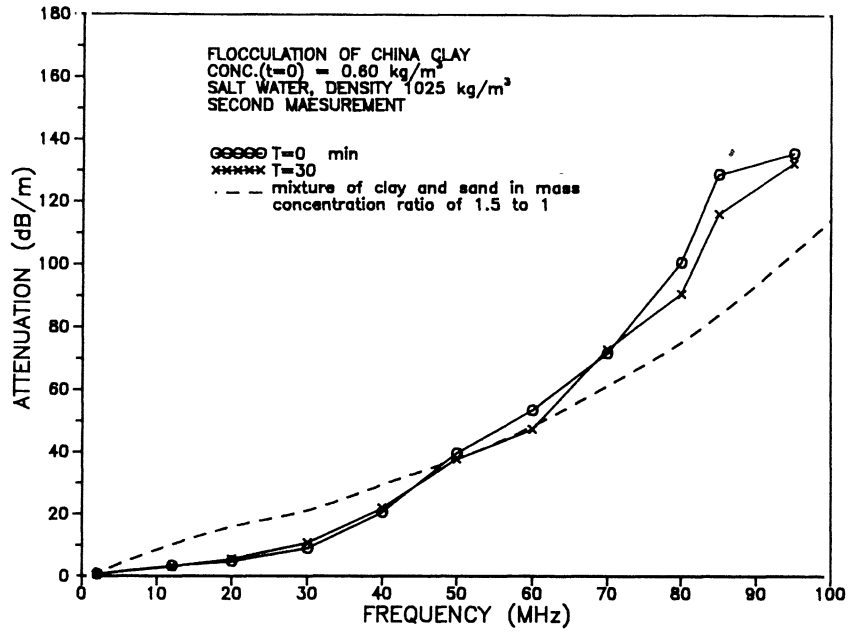


Fig. 4.2 Acoustic attenuation spectra of China Clay suspension. Comparison between the unflocculated situation (at t=0) and the situation of maximum concentration of flocs.

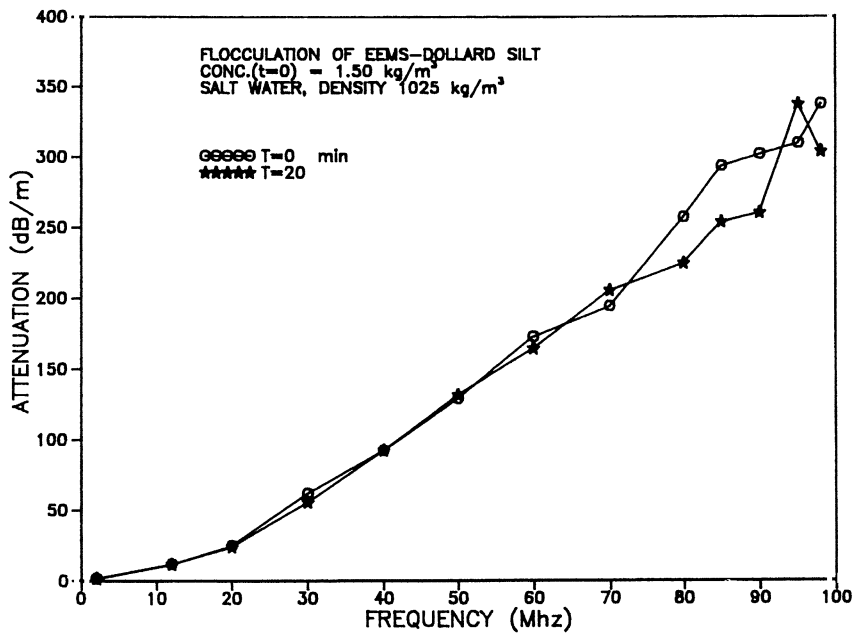
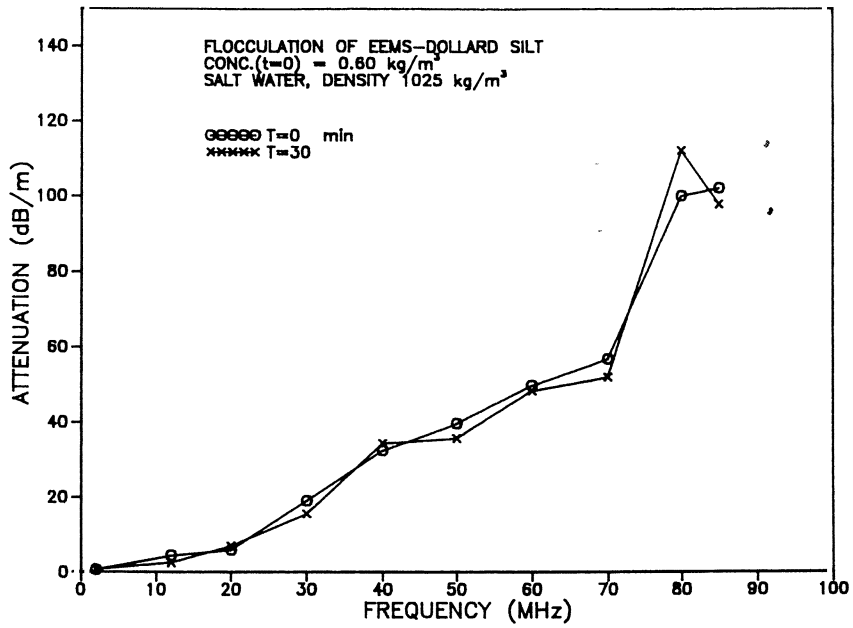


Fig. 4.3 Acoustic attenuation spectra of Eems-Dollard silt suspension. Comparison between the unflocculated situation (at t=0) and the situation of maximum concentration of flocs.



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