Supreme Court Civil
Contracts of Insurance — collapse of silos — whether due to weakening of structure by hurricane or by faulty design and construction
Whether defendants (insurers) liable. Judgment for defendants.
Expert Evidence [Assessment]
No cross-references [See pro forma

IN THE SUPREME COURT OF JUDICATURE OF JAMAICA

IN COMMON LAW

SUIT NO. C.L.1989/J192

BETWEEN	JAMAICA FLOUR MILLS LIMITED	PLAINTIFF
AND	WEST INDIES ALLIANCE INSURANCE COMPANY LIMITED AND OTHERS	DEFENDANTS

JUDGMENT

OF THE HONOURABLE MR. JUSTICE PANTON

JULY 28, 1994

IN THE SUPREME COURT OF JUDICATURE OF JAMAICA
IN COMMON LAW

SUIT NO. C.L. 1989/ J 192

BETWEEN JAMAICA FLOUR MILLS LIMITED PLAINTIFF

AND WEST INDIES ALLIANCE INSURANCE CO.LTD.
AND OTHERS DEFENDANTS

Richard Mahfood,Q.C.,David Muirhead,Q.C.,Wendel Wilkinson,and Karen Robertson, instructed by Vincent Chen of Clinton Hart and Co., for the plaintiff.

Emile George,Q.C.,W.K.Chin See,Q.C.,John Vassell, and Ingrid Mangatal, instructed by Dunn,Cox and Orrett, for the defendants.

Heard: January 25 -27; February 1,2,4,5,8,9,11,15,17,18,22,23,25;
March 1-3,8,9,11,15-18,22,24,25; May 10-13,17-20,25,26;
June 1-3,8,9; July 14,15,21,28; September 20,22,23,29;
October 4-7,11-14,19-21,25-28; November 1-3,30;
December 1,8,10,13,14, **1993.** and July 28,**1994.**

Supreme Court - Civil
Contracts = Policies of Insurance } Liability of Insurers (defendants).
exposed to hurricane = whether weakening of structure by hurricane effective
Cause of collapse or whether collapse due to faulty design and deficiency
in construction - aftermath - whether plaintiff failed to take reasonable
precautions for maintenance and safety of silos after hurricane in breach
of conditions of policies. [Judgment for defendants]

No cases referred to

Expert Evidence - assessment

PANTON, J.

The trial of this common law action commenced on January 25, 1993, and ended on December 14, 1993, after seventy-six days of hearing. The Queen's Counsel involved in the trial have said that this is the longest common law trial that has taken place in Jamaica. That I dare not question, given their senior status at the Bar and the fact that I have not seen any record of a longer one.

The evidence presented was of a very technical nature, requiring much concentration on the part of those who were required to listen to it. The numerous engineering reports and other documents that were tendered in evidence required no less attention. Indeed, there were ninety-eight (98) exhibits, all of them, with the exception of one, being of a documentary nature. One of these exhibits, it is noted, is in French.

THE PLEADINGS

The statement of claim

The plaintiff is a limited liability company with registered office at 209 Windward Road, Kingston 2, and is engaged, inter alia,in the business of milling wheat into flour, and sale of the said flour at the said premises. The defendants are companies (local and foreign) that carry on the business of insurers and as such they had collective policies of insurance between themselves and the plaintiff.

The plaintiff's claim seeks to recover from the defendants sums of J$ 14,386,571 and US$ 4,964,510 in respect of property damage; and J$ 31,390,452 in respect of "loss of gross profit etc., wages and auditors fees". The consequential loss was subsequently agreed at J$ 25,000,000, in the event of the defendants being held liable.

The first nine (9) paragraphs of the claim are admitted by the defence. They relate to the identity of the parties and refer to the risks insured and the amounts of the insurance coverage. The first sign of disagreement between the parties is seen in paragraph ten (10). It provides the area of major disagreement between the parties. Without hesitation, it must be quoted now. For completeness, and indeed for a clear appreciation of the issues, paragraph eleven (11) and a portion of paragraph twelve (12) will also be quoted.

Paragraph 10.

"On the 12th day of September 1988, Jamaica, and accordingly the Plaintiff's premises at 209 Windward Road, Kingston 2 was subjected to the forces of Hurricane Gilbert, the most or one of the most devastating and violent hurricane(s) experienced and recorded in Jamaica. In consequence silos 10 and 18 together with other silos being part of the property insured were subjected to stresses which weakened them and such weakness persisted and was 'locked in' to the structure and continued to influence the integrity without being apparent and was then unrecognised and was the proximate and effective cause of a sudden and violent rupturing of the structure which occurred on the 26th day of September 1988 when the silos were being filled as hereinafter pleaded in paragraph 12. Additionally, the Plaintiff details, calculations and reasons of the mechanics of failure and/or cause of collapse as set out in reports numbers Phase 1 to Phase 6 inclusive by Zetlin-Argo Structural Investigations, Inc. copies of which reports have been delivered to the Defendants."

Paragraph 11.

" That at all material times and on the 26th day of September 1988 and at the time of the loss and damage hereinafter mentioned the

Plaintiff was interested in the said property hereinbefore specified under paragraph 6 above to the extent of the said amounts of $257,800,000.00 and $93,060,000.00 so insured thereon respectively."

Paragraph 12

"On the 26th day of September 1988 during the filling of grain in Silo 10, whilst the said policies were in force, buildings, machinery, plant, equipment, stock in trade and other contents were damaged or destroyed by or through or in consequence of the insured perils, to wit, by or as a result of the damage caused or occasioned by hurricane Gilbert on the 12th day of September 1988

as hereinbefore pleaded and in the alternative in the case of the Principals of the 14th named Defendants and the 15th to the 39th named Defendants by way of subsidence and collapse whereby the Plaintiff has suffered loss and damage to the property insured and loss of gross profit, wages and auditors fees in respect of the interruption and/or interference of its business."

The Defence

The defence admits that the premises were subjected to the forces of Hurricane Gilbert, and that there was a rupturing of the structure of the silos which occurred on the 26th September,1988, immediately following the filling of silo 18, and during the filling of silo 10.

The defence however denies that any stresses created by the forces of Hurricane Gilbert weakened the premises or were locked in to the structure, or influenced the integrity thereof or that the forces of Hurricane Gilbert created any stresses which were the proximate or effective cause of the rupturing of the structure.

The defence alleges that the proximate or effective cause of the rupturing of the structure was faulty design and detailing, and deficiency in construction. The particulars are as follows:

"(i) The reinforcement as detailed on the design drawings provided insufficient overlap between bars to allow the tensile force in one set of bars to be safely transferred to the continuing bars under normal operating conditions.

(ii) The reinforcement at the junction of the outer walls is discontinued near the point of highest stress with all bars terminating in the same location.

(iii) Detailing the splicing and anchoring of bars at the same point at the different splice points around the perimeter of the silos without providing for proper overlap to ensure the safe transference of stress.

(iv) Misplacing the designed reinforcement during construction in that the bars in the joint between the outer walls of silos 10 and 18 were not all hooked around the jacking bar as called for on the drawings.

(v) Failure of the design drawings to stagger the position of the laps in the reinforcement as required by good practice and requirements of Codes of Practice or, alternatively, to take special precautions to ensure that stresses can be safely transferred between the re-inforcing bars.

(vi) Failing to back fill around the elevator pit and tunnel with mass concrete or specifically compacted soil.

(vii) The cross-sectional area of reinforcing steel as detailed on the design drawings is less than that which would have been specified by a prudent designer using information available in 1966 on the pressures developed by grains in silos.

Alternatively, if the Hurricane caused defects in the structure of the silos, which is denied, the Defendants will say that the Plaintiff is not entitled to indemnity in respect of the alleged loss by reason of its failure to take reasonable precautions for the maintenance and safety of the silos or to carry out any or any reasonable or adequate inspection of the said silos after the said Hurricane in breach of Condition No.4 of the Special Perils extension to Policy No. C1067 and Condition No. 5 of Policy No. 551 FAFR 147.

Further, whether before or after the said Hurricane, the Plaintiff failed to carry out any or any reasonable or adequate inspection of the said silos in breach of the aforesaid conditions.

No admission was made as to paragraph 11; nor was there any admission as to the extent of the damage or loss alleged in paragraph 12. There was also a denial that there was any loss or damage arising out of any insured peril.

ISSUE FOR DETERMINATION

It seems to me that on the pleadings, the clear issue for determination is whether on the 12th September, 1988, silos 10 and 18 were subjected to stresses which **weakened them; whether such weakness persisted and was 'locked in' to the structure**, and continued to influence the integrity thereof, without it being

apparent, **and was the proximate and effective cause of a sudden and violent rupturing of the structure** which occurred on **the 26th September, 1988,** when silo 10 was being filled.

In his opening of the case for the plaintiff, learned Queen's Counsel, Mr. Mahfood, in making 'three general observations' said that 'the real inquiry is what caused the collapse'.
Firstly, he said, the issue in the case is not whether building codes were complied with; the issue is not whether or not there was a factor of safety because "the true and final test and the acid test of the factor of safety is not engineering calculations but the acid test is the test of history. The acid test of the safety factor is that for over twenty-two years the building operated comfortably and that is the acid test because when the building is finished the building doesn't know anything about building codes; there is the structure there and the acid test of history is the best test of the safety factor, and therefore, the real enquiry is what caused the collapse and the only reasoned presentation consistent with the facts of history is the presentation in the Zetlin-Argo Phase 6 report".

In making his other general observations, Mr. Mahfood remarked that the thought that engineering is an exact perfect science is a myth. He added the following words: "The thought that engineering is an exact mathematical science is a myth. Behind every mathematical computation are numerous judgmental calls. Behind every mathematical calculation, judgments have to be exercised by the engineer; it needs judgment and therefore the idea that everything is only (a) number is a myth. There is much need for judgmental calls in engineering as there are in the legal process. Critical to any analysis of cause of failure at every step of the way are judgments by the engineer.....".

At this time, there is no intention of discussing the merits or

otherwise of the learned Queen's Counsel's observations on the nature of engineering. That which requires immediate note is his position that the real inquiry is: what caused the collapse?

Did Hurricane Gilbert do that which the plaintiff has attributed to it so far as the silos are concerned? The answer lies in the evidence which we shall now look at.

THE EVIDENCE

As indicated earlier, many reports and other documents were tendered in evidence. They were all admitted by consent. The Court considered them all. They were assessed and evaluated particularly for relevance, credit worthiness and accuracy. Several witnesses were also called.

The evidence produced by the plaintiff

1. The plant and the accident

The silos were constructed on the basis of drawings done by Mel Jarvis Construction Co. Inc., general contractors of Salina, Kansas, U.S.A. These drawings bear dates ranging from September 1966 to February,1967. Since 1968, Pillsbury Co. of Minneapolis, U.S.A.,has had the management of the Jamaica Flour Mills. In 1988,the processing capacity of the plant was 12,500 cwt or bags daily. Normally, grain arrives in ships; unloading takes place on premises adjacent to the plant, and a conveyor belt takes the grain to the silos. There are 25 bins in all. The external walls of the silos are circular, whereas the internal walls are hexagonal in shape. Grain is loaded north, south together alternately, then the centre bins are loaded. During unloading, the outside bins are first done, proceeding in an orderly manner from one end to the other. Centre bins are usually unloaded lastly. A general rule at the plant is to try to load the silos as uniformly as possible, particularly at the time of first loading of a silo. The reason for

uniform loading, according to Mr. John Ruland, the managing director of the plaintiff, is to get a uniform settlement of the facility.

It is a notorious fact that Hurricane Gilbert struck Jamaica on the 12th September, 1988. At that time **both silos 10 and 18 were empty**. On the following morning, Mr. Ruland visited the plant. All operations had ceased. There was no power supply. He said that he and the guards who had been on duty without relief went around the silos, inside the silos, into the tunnel and then left. According to him, he conducted a four hour inspection of the plant, looking specifically for structural damage. He observed that the roof structure between the two silos was damaged. Several windows in the milling facilities had been broken and blown out. There was damage to a bridge between the A and B banks of the silos. The roof over the engineering shop had been completely blown off.

The plaintiff maintains an engineering department which at the time of Gilbert had over 20 employees. Whenever there are events such as seismic episodes, a Mr. Will McKoy, who is an engineer, is usually called in to inspect. Mr. McKoy was called in after the hurricane. He, according to Mr.Ruland, made a report to the plaintiff's operations manager. However, we do not have the benefit of that report. Mr. McKoy repaired the damaged bridge.

On 25th September, 1988, silo 18 was loaded for the first time in its history.

On 26th September, 1988,while silo 10 was being loaded, there was an apparent failure of the joint between 18 and 10. It should be noted that the uniform loading referred to earlier as the recommended method was not followed in the case of this loading on the 26th September, 1988. The control room was located under silo 18. Three employees who were in that room at the time of the failure unfortunately perished. The weight of the grain did

extensive damage to walls, floors and beams. The production facilities were rendered inoperable.

The management of the plaintiff sought an analysis of the facility, and contracted Zetlin-Argo Structural Investigations, Inc. of the U.S.A. to investigate the accident. The cost of the investigation was an astonishing sum of US $598,000.00. In due course, we shall look at the nature and quality of the investigation that attracted this fee, which appears enormous even by Jamaica's inflationary standards.

2.The hurricane

Meteorologist Calvin Gray was at the weather forecasting centre at the Norman Manley International Airport from the 11th to the 14th September, 1988. During the period, hurricane force wind at the centre lasted for 3/4 hour; storm force winds lasted for 9 hours, and gale force winds lasted for 16 1/2 hours. The average speed of the wind on the 12th was 110 knots. One knot is equal to 1.1521 miles per hour. The movement of the system was from east to west. However, the motion of the wind as it moved towards Jamaica would have been out of the north. **The direction of the wind, he said, was not recorded as the anemometer malfunctioned due to the loss of power. It appears that eventually the equipment was blown away.** With respect to hurricanes, there is a counter-clockwise flow; hence, when the hurricane approaches a particular point the winds will be out of the north and after the eye has passed the wind will come out of the opposite direction, that is from the south. Before the loss of the equipment, a gust of 114 knots was recorded at the forecasting centre. The winds coming out of the north were stronger. This was due to the effect of the mountains running from east to west.

In terms of rainfall, Hurricane Gilbert was moderate in that it produced only eight inches over a 24 hour period. In terms of

windspeed, the records show that it was the worst for this region. In relation to pressure which is the most damaging component of a hurricane, according to Mr. Gray, we were spared of this most damaging component.

3. The Zetlin-Argo investigations

Dr. Lev Zetlin, President of Zetlin-Argo Structural Investigations Inc., and Mr. Kazimierez Cader led the investigations into the cause of the failure. Unfortunately, we did not have the benefit of seeing and hearing Dr. Zetlin as he passed away on the 4th December, 1992, a mere seven and a half weeks before the commencement of the trial.

According to Mr. Cader, it was Dr. Zetlin who projected the direction for analysis, whereas the major area of work for Mr. Cader himself was the engineering calculations. Dr.Zetlin wrote the reports but they were sent to him Mr. Cader for consultation. **No report was issued, said Mr. Cader, without his (Cader's) approval.**

Mr. Cader is a Polish citizen resident in the USA since 1981.He holds a Master's degree in structural engineering. His thesis was on pre-stressed concrete shells, innovative approach to design. He has been designing buildings since 1971, and has been an engineering consultant since 1987. Prior to this case, he had never testified in a court of law.

Dr. Zetlin and Mr. Cader visited the site on October 12, 1988. **They immediately formed a preliminary opinion of the cause of the failure.** On October 18, this preliminary opinion was communicated to the Pillsbury Co.-see Ex.5. This is how they expressed their opinion--

"1. Neither the details as shown on the design drawings nor the construction had any role in the cause of collapse.

2. The cause of the collapse was the unusual and unpredictable acts of nature, including the recent hurricane Gilbert which preceded the collapse.

3. Contributing factors to our present opinion are:

a. The mode of rupture, specifically of the wall between bins 10 and 18, as viewed from the observable distance. **The mode seems to indicate a vertical shear failure, rather than a direct tension failure in the wall.**

b. Engineering history shows that structures which served their purpose safely for 20 or so years do not collapse suddenly, unless

(i) there was a sudden change in the service function of the structure,

(ii) there was chemical deterioration of the concrete and/or of the reinforcement,

(iii) the structure was subjected to unpredictable external forces,

(iv) occurrence of unpredictable violent acts of nature.

In this case, the service function of the structure has not been changed from what it was for many previous years and there are no visual signs of chemical deterioration of either the concrete or of the reinforcement."

This opinion, Ex.5, has been titled Phase 1 Volume 1 by Zetlin-Argo. There were several other Phases exhibited by the plaintiff, culminating with the popular Phase 6 which occupied a substantial portion of the trial.

Let us at this stage return to Phase 1 (Ex.5) and notice that the appearance of a vertical shear failure referred to in 3(a) above was not subsequently substantiated.

According to Mr. Cader,the statement at 3(b) above applies to all structures, as far as he understands, from an engineering point of view. "Exactly the same considerations would apply in this respect to a garden wall which is supporting nothing and to a silo wall that is being subjected to loading and unloading of grain". So said Mr. Cader in cross-examination.

All components of the structure connected to the area of collapse were checked, according to Mr. Cader. He found the factor of safety sufficient for normal operational load. Samples of concrete were taken from the debris and tested in the Chicago laboratory of Wiss, Janney, Elstner Associates Inc. In calculating the safety factor, Zetlin- Argo have said that they used their engineering judgment to choose the lowest available concrete strength taking into account the possible coincidence that they had everything there in the area where the collapse occurred.

Usually, the strength of a piece of concrete is determined by statistical calculations. In the instant case, that method could not be used as there were too few readings. Zetlin-Argo had therefore to rely on their engineering experience, and knowledge rather than on mathematics.

The primary cause of collapse was the crack in the haunch. Based on an embedment length of six inches, the safety factor was calculated at 1.4.

In examination-in-chief, Mr. Cader, in commenting on the detailing of the reinforcement in the critical joint, said that if he had been designing the structure he would not have done it in the way

that it had been done. He would have provided the required overlap in the joint. Although he would have so done, he was nevertheless of the opinion that having calculated the strength of the joint in all critical cross sections, the safety factor was appreciable.

As indicated earlier, Phase 6, that is Ex. 18, was a significant feature of the trial. At page C3 thereof, Zetlin-Argo expressed their conclusion as to the cause of the failure. In bold capitals at the head of the page, Zetlin-Argo said **"Cause of failure of bins 10 and 18 on September 26,1988, was hurricane Gilbert, which hit the bank of silos on September 12, 1988, inflicting its greatest damage at the bottom of the bins within the junction between bins 10 and 18, as shown in Fig. C-7".** In his evidence, Mr. Cader listed five steps that they had undertaken to "calculate the cause of failure". I summarize these steps thus:

1. finding out the horizontal load created by Hurricane Gilbert;

2. calculating the soil pressure including the horizontal force created by Hurricane Gilbert;

3. calculating the soil settlement due to the dead load, the live load and the Hurricane Gilbert load;

4. computer calculations of the three dimensional model of the eastern end of the silo bank; and

5. calculating the internal stresses caused by the differential settlement and comparing them with the capacities.

So far as the first step was concerned, which was really a determination of the wind forces on the silo bank, Zetlin-Argo through Mr. Cader said that they did research in the area of wind engineering and then they consulted with a Dr. Emil Simiu who

provided them with a report which was admitted in evidence as Ex.24. Dr. Simiu did not give evidence. Instead, the plaintiff called as a witness Professor Peter Robert Sparks who commented on Ex. 24 and on the work of Zetlin-Argo in this area.

In a summary displayed at page G1 of Ex.18 dealing with this area of the case, Zetlin-Argo states:

"On September 12, 1988, during its first passage over the JFM silos, Gilbert caused a tremendous increase in pressure on the soil under the southeast corner of the mat foundation. The resultant pressure exceeded any previous pressure that the silos had been exposed to.....

"Simultaneously, there were vacuum pockets in the narrow passageways between bins 10 and 18 and the adjoining ancillary buildings; also, there was a drop in the pressure in the atmosphere. Both of these effects created an outward air pressure on the walls from the inside of the bins 10 and 18 in the same direction as grain in the bins does in normal service of the bins".

Further, at page G7 of the said Ex.18, Zetlin-Argo, in referring to the data and methodology used in this area of the investigation, asserted that the engineering methodology employed in the analyses and the calculations is widely accepted for evaluating the effects of hurricanes on structures.

At page G26, under the heading **Role of a Wind Tunnel Test**, Zetlin-Argo informs us that consideration was given by them so far as the running of such a test was concerned **"to determine the aerodynamic effects (of forces and localized pressures in the bins) of a hurricane with numerous unknowns on the geometrically complex structure of JFM with the unusual combination of a headhouse, serrated exterior facade and the narrow passageway and spaces, all**

of which were creating vortices". However, the idea of the test was discarded as Zetlin-Argo felt that an attempt at such an exercise would be futile and it would not supply any applicable conclusions within a known degree of accuracy, however rough.

This position adopted by Zetlin-Argo bears comparison with the report of Dr.Simiu at page 6 of Ex.24. There, Dr. Simiu had this to say:

"Owing to the presence of the ancillary buildings near the northeast corner, aerodynamic effects will be somewhat different for the west and east halves of the silo building. For this reason the value of the total wind force and torsional wind-induced moment will differ from those that would obtain in the absence of the ancillary buildings. **These differences cannot be estimated accurately without conducting wind tunnel tests.** However, it is reasonable to assume that they are small and are neglected in the calculations that follow".

Both Professor Sparkes and Mr. Cader expressed agreement with this section of Dr. Simiu's report. Later, we shall refer to their evidence.

In relation to Zetlin-Argo's second step in their investigations, a calculation has been put forward on Sheet G40 which is part of Ex.18. It is this calculation that was given to the soil expert as the basis of the work in this area. The calculations on this sheet show the total soil pressure due to dead load, live load and wind load. The term wind load is self-explanatory; dead load refers to the weight of the structure, and live load means the weight of the grain.

The third step by Zetlin-Argo is the soil settlement calculation by Joseph Ward and Dr. Oweis. In Ex.18 at the page marked Appendix F1(1), there is a letter dated 25 May,1989, signed by Oweis and

Ward setting out a summary of their investigation. Soil samples were taken from borings that they said they had done; and, laboratory tests were conducted on the samples. The results of their settlement analysis are shown in the attached Table 1.

On the 9th March, Mr. Cader said that this table was inaccurate. He acknowledged the deficiency and attributed it to the very tense time related situation that faced them when they were dealing with the soil experts.

In Ex.20, Messrs Ward and Oweis set out their investigations and calculations, and concludes at page 23 thereof as follows:

"Based on the analyses herein, we conclude that loads from Hurricane Gilbert have caused settlements. Our best estimate of such settlements is presented in this report."

They placed limitations on their work, as on page 24 of Ex.20 they state that there may be subsurface conditions not disclosed by the explorations.

On page F1 of Ex.18,the summary of their findings is as follows:

" Forces and torques generated by Gilbert increased pressures on the soil along the south facade of the silos, with a very large increase in the pressure on the southeast corner of the mat foundation with respect to the southwest corner (see Fig.F-3).
" This difference in pressure on the soil resulted in about a 1.72 inch larger settlement at the southeast corner than at the southwest corner on September 12,1988 - shortly after Gilbert- and by about 2.22 inches larger on September 26,1988, when the failure occurred (see Figs.F-4 and F-5).

It should be noted that Professor Sparks gave evidence that the torque as calculated by Zetlin-Argo was in the wrong direction.

The fourth step in the investigations by Zetlin-Argo involved the computer analysis. This, according to Mr. Cader, was aimed at finding out the internal forces due to the structure distortion caused by differential settlement. Messrs Wiss Janney etc found between bins 19 and 24 a measured tilt of .75 inch at bin 19 and 6.5 inches at bin 24. They also had calculated , based upon the soil expert's report, a differential settlement between bins 10 and 24 of 1.11 inches. According to Mr. Cader, the measured tilt corroborated with the differential settlement, if the silo bank is viewed from a geometric point of view.

For their computer analysis, Zetlin-Argo originally used 1.25 inches of differential settlement which they had obtained prior to the final results. It was what Zetlin-Argo said may have been called the differential between differentials. It was the subtraction between the west and east differential settlements. After receiving the final report from Oweis, they calculated the differential settlement as 1.11 inches between the bin numbers 10 and 24.

In constructing the silo model, Zetlin-Argo used only the eastern part of the silo bank for their analysis. They modelled seven bins. They used certain boundary conditions to represent the pit and tunnel which are located at the eastern end of the silo bank, and created boundary conditions to substitute for the rigidity of the remaining silo bank. The only material that they used in their calculations was concrete. The load that they used was the vertical load represented by the weight of the silo bins multiplied by five for the remaining dead load and for the grain load. In all this, they assumed that the settlement calculated by the soil experts due to Gilbert remained after Gilbert.

In their calculations, Zetlin-Argo (through the words of Mr. Cader), arrived at certain figures indicating a deformation caused by the settlement. In order to bring that deformation to the calculated settlement of 1.25, they multiplied by 2.5 This resulted in the final force used for structural analysis being calculated as 39.38 kips.

The fifth step was a structural investigation of the critical joint on the day of the collapse. This involved a calculation of the internal stresses. Zetlin-Argo at this stage, again through Mr. Cader, wishes that this analysis be viewed as being presented in a range of capacities and forces. Some numbers are not very precise, due to many variables. Hence, there is a range of capacities and a range of stresses. Failure occurred within that range. Zetlin-Argo concluded that there were large internal destructive forces at the bottom of the junction between bins 10 and 18; that the failure originated there; and that these destructive forces reached a value of 44.89 kips which is equal to the strength of the junction (see fig.M-11, Ex.18).

The general picture painted by Zetlin-Argo is that their calculations, computer runs, soil explorations and general observations and investigations indicate that silos 10 and 18 were structurally sound in every respect; that they were suited for the use for which they had been constructed; and that the failure was due to the after effects of Hurricane Gilbert.

4. The witnesses

In opening the plaintiff's case, learned Queen's Counsel, Mr. Mahfood, indicated his intention to call five technical witnesses, including a Dr. Wayne Reid whom he described as one of Jamaica's leading structural engineers. On February 22, 1993, learned Queen's Counsel again referred to the calling of Dr. Reid. In the end he called four witnesses, excluding Dr. Reid. Those called were Calvin

Gray, meteorologist, Kazimierez Cader, Professor Peter Sparks and Dr.Issa Oweis. By far the most important was Mr.Cader. His evidence ranged over the whole sphere of the case whereas the others confined themselves to the wind (Messrs. Gray and Sparks) and to the soil (Dr, Oweis). They were all vigorously cross-examined. One witness (Professor Sparks) described the cross-examination as combative in nature. Even if there was the intention, it would be impossible and undesirable in this judgment to quote most of the evidence given at the trial. After all,the notes of evidence occupied over six thousand typed pages measuring generally 14 inches in length and 8 1/2 inches in width. It is therefore proposed to make reference basically to those major areas of the evidence that go to the root of the issues for determination.

Mr. Cader has to be given pride of place so far as the case is concerned. Reference has already been made to his qualifications and experience. The nature of the case brought into question the strength of the concrete in the silos at the critical joint, the nature of the reinforcement, the effect of the wind and the direction of the torque, the nature and performance of the soil, the behaviour of the silos, and the worth of the computer runs. It should never be forgotten that Mr. Cader's prime responsibility as determined by Dr. Zetlin
was in the area of calculations.

Mr. Cader on concrete

Mr. Cader advised the Court that he was not an expert in concrete technology. Tests were conducted to determine the compressive strength of the concrete. These tests were performed by crushing the cores. An impact hammer test was also performed. The latter test is not as reliable as the former. Honeycomb and some cracks were between the cores. Honeycomb indicates that the concrete is not "the very highest quality". Honeycomb would be weak. As far as he could see, no honeycomb was in the haunch--**although he did not state that fact in any report.** The majority of the core samples

taken were not suitable for testing although the cores had been taken from positions determined by the plaintiff. If concrete is going to crack, it does so at its weakest point. Concrete is as strong as the weakest portion of it. He saw no need to test the honeycomb to get a true picture of the results of the test. **If the honeycomb had been used in the test, it would have brought down the value of the test results. In conducting the concrete test, no account was taken of the fact that the silos were subjected to cyclical loading.**

The compressive strength of concrete is important as in order to get the bond strength of the concrete it is necessary to use the compressive strength in the calculations.

Mr. Cader testified that there was a series of old cracks in the bins, and that these cracks did not arise from the collapse. He added that there were numerous narrow cracks that were not apparent to the naked eye. They were at the bottom of the curved walls of the bins and in the area of the partition. He noted that there was rusting on horizontal bars, and that this rusting resulted from old cracks from the outside migrating to the steel. Where there are old cracks, there would be no tensile strength in the concrete.

The ratio of water to cement is an important element in determining the strength of concrete. In the silos, the water/cement ratio was higher than one would expect. It was 65 to 75. When one goes beyond 55, there is too much water in the concrete. In the instant case, there was between 12 and 13 percent too much water in the concrete.

Mr. Cader on reinforcement

Mr. Cader testified that the reinforcement did not meet the desired requirement in that it did not reach the jacking rod. At least seven bars in one photograph of the damage that was shown to him did not go around the jacking rod. The bars were not broken; they had pulled out. This indicated that there had been bond failure.

The purpose of reinforcement in concrete is to take up the tensile load. Tensile stresses are caused by tensile load, and tensile stresses cause cracks in concrete.

In the haunch, there was an absence of splicing. If there had been splicing, there would have been a greater distribution of tension from bar to bar over a larger zone. That would have placed far less tensile stress in the concrete in the haunch. Proper splicing was needed. The design for splicing was not perfect.

There was a bar anchored into the concrete at the haunch. This transmitted the tension into the concrete which then transmitted it to the next bar into the outer wall which is also anchored into the haunch.

There were hooks in position. Their presence would have increased the local tensile stress distributed in the concrete in the haunch. Instead of the hooks, there should have been splicing so that the tension would have gone from bar to bar over a larger zone created by the splice. If there was splicing, there would have been a greater distribution of tension from bar to bar over a larger zone. That would have placed far less tensile stress in the concrete in the haunch.

All the steel ended up in the same vertical plane, not having been staggered.

Mr.Cader on the tilt

To Mr. Cader, it is obvious and logical that **unless there is information as to the existence of a tilt before Hurricane Gilbert, one cannot tell whether or not any tilt was caused by Hurricane Gilbert.** He does not know whether the silos were built with a tilt, and there was no source from which to get any information as to the existence of a tilt before Gilbert.

The ACI-71 provides for a perfectly properly constructed structure having a tilt of up to four inches. There is provision for silos over 100 feet in height being four inches out of plumb. The silos in the case were built with some out of plumbness.

Mr. Cader was unable to say, without measurement, whether there was even a slight differential settlement before Hurricane Gilbert.

Mr.Cader on differential settlement

In the calculations in Appendix F-1(3) in Exhibit 18, precise numbers were not used. There is a deficiency in the Table presented here relating to settlement at the southeast corner.
There is an unvarying pressure caused by the weight of the structure. This pressure is called dead load. The pressure exerted on the soil by the grain is known as live load, and that depends on the distribution of the grain in the various bins. If all the bins are full or nearly full, pressure would be evenly distributed, that is, there would be uniform pressure on the soil.

Mr. Cader does not have, and apparently did not use, the statistics of the history of the loading of the silos.

Differential settlement cannot be determined by soil exploration. It may be determined only by measurement, or it may be approximated by analysis. All the settlements were calculated. **There were no measurements.**

Tests were done on the soil and as a result of those tests, Mr. Cader combined his experience with his engineering knowledge to arrive at the conclusion that there was uniform settlement before Hurricane Gilbert.

Mr.Cader on wind

Mr. Cader said he was not an expert on wind. He nevertheless had calculated the mean torque arising from the passage of Hurricane Gilbert. Having listened to the evidence of Professor Sparks, Mr. Cader then testified that he had calculated the torque in the wrong direction. Indeed, it should have been in the opposite direction. Had that been done, the calculations would have shown that the worst vertical soil pressure due to Gilbert occurred in the southwest corner.

In Appendix 1 to 4, the incorrect torque has been used to calculate the distribution factors. The incorrect torque has been used on every line, so every line is wrong. **It is on the basis of the wrong figures that the soil expert arrived at the settlements on which reliance has been placed.**

In calculating the speed of the wind from the north, Mr. Cader said that he treated the silos as a typical building with plain surfaces, normal to the wind, rectangular in plane and sharp edges. However, he agrees that the structure of the silos was not that of a typical building with plain surfaces.

Mr.Cader on the emptying of the silos

As far as Mr. Cader was concerned, the silos (10 and 18) had their outlets on the side. The position of the outlets, he said, is of importance in relation to the flow pattern on emptying. This would affect the distribution of the stresses on the walls of the silos when emptying of the silos is taking place. Depending on the nature of the grain, the angle of the cone formed on emptying would vary. That cone will either be along the walls of the silo, or form its own cone with its own mass. Where the cone meets the vertical faces of the silo, there is a band called the transition band. The band could be up to 50 or 60 feet up the wall of the silo. In this transition band, the grain has to change from flowing vertically

downwards to flowing towards the outlet. The change causes high stresses to be exerted horizontally on the face of the wall in the region of the transition band.

In commenting on extracts from Exhibit 34, Mr. Cader said that the slope of the bottom of silos 10 to 18 was far too shallow to allow mass flow, that is, a condition in which the grain would slide continuously along the entire slope of the bottom hopper from the outlet to a point at the junction between the top of the hopper slope and the vertical silo wall.

Mr. Cader said further that it was evident that the exterior walls of silos 10 and 18 were subjected to far higher loads during the discharge of grain than were the walls of any of the other exterior silos, with the possible exception of silo no. 11.

Having agreed with that position, Mr. Cader nevertheless said that it was pure speculation to say that the exterior walls of silos 10 and 18 and their connection to the partition wall were subjected to a far higher load than any other similar haunch connection in any other part of the structure, and so failure would be expected here first.

Mr. Cader on the computer runs

The purpose of the computer runs was to find out the stress concentration due to structure deformation. To do so, the intention was to simulate as closely as possible the actual conditions in and relating to the silos. **However, in the first computer run, the conditions were not simulated.**

Mr. Cader agrees that several pages were stage-managed to indicate that there had been a settlement.(see page 2529 of the transcript). Notwithstanding the stage-management, he agrees that when one compares the calculations for nodes 21 and 25 there is an

inclination of the settlement towards the west. In relation to node 11, a load equivalent to the weight of three full grain loads , three full silos, was placed there. Mr. Cader's evidence was also that having arrived at certain figures, he multiplied by 2.5 to accommodate the result that the soil expert had arrived at.

It is important to add at this stage that the final report of Zetlin-Argo which is set out in Exhibit 18 relies on computer run number one.

The second computer run was a demonstration intended to show that the calculations were correct. In this run, the correct value of concrete was not used. The nodes were fixed to make the structure more rigid than it should have been. All parts of the silo are equally loaded at five times the weight of the concrete walls and roof, pre-supposing that the grain is equally spread between the silos. According to this computer run, the northern side of the silo has a greater settlement in the west than in the east. That is the position also on the southern side of the silo. In the second run, Mr. Cader said that he did not multiply by 2.5 as he had done in the first run. This run showed a displacement to the west. It should also be noted that in this run no wind intake was computed; Mr. Cader just used the settlement generated by the wind load.

On the whole, Mr. Cader was not happy with computer run number two.

The third computer run has no input in relation to the pit, the tunnel, the headhouse, or the wind load. The various inaccuracies in the other runs were repeated in this run.

The fourth computer run did not have in it the grain load that existed at the time of the collapse; it had no pit, no tunnel, no tower. The boundary conditions were wrong. This run was intended to simulate the results of the calculations of the soil expert; it was not intended to simulate the actual soil condition. The soil

expert, incidentally, was not given the figures for the actual load distribution at the date of collapse. Instead, he was given an average load.

Mr. Cader's overall position so far as the computer runs are concerned, is that the information that was put in was done on the basis of his assessment of the structure and his engineering experience. **He is on record further as saying that he would rather rely on his engineering judgment than on the computer results.**

Professor Peter Sparks

This witness is a Professor of civil engineering and engineering mechanics at Clemson University, South Carolina, U.S.A. He is an Englishman who moved to the USA in 1977. He has a Bachelor of Civil Engineering degree from the University of Bristol, and a Ph.D. from the University of London.. His area of specialization is structural engineering. His early work was on the behaviour of structures. In the early 1970s, he began working on the response of buildings to wind and earthquake. He has a further area of specialization which is the use of wind tunnels in determining the pressures and loads on buildings and structures generally. The first hurricane that he investigated in detail was apparently Hurricane Diana in 1984, followed by Hurricane Elaina in 1985. In 1989, he did extensive work, he said, on Hurricane Hugo where he simulated the wind speed measurements.

Unlike Mr. Cader, the professor has testified in Court once before. His first visit to Jamaica to investigate the circumstances of this case was between January 13 and 16, 1993, that is, a few days before the trial commenced and more than four years after the collapse of the silos. On this visit, he flew in a helicopter around the area to look at the site of the anemometer at the Norman Manley International airport. Professor Sparks' task involved an assessment of the wind effect on the structure. It was necessary

for him to determine how the wind flow is modified as it approaches the Flour Mills. That was one of the purposes of the helicopter ride. He also flew around Long Mountain and the approach to the plaintiff's premises. He found the zone around the mountain a very turbulent one.

In his investigation, the professor reviewed Exhibit 18, Part 3. He used Ex. 37A, which is an ordinance survey map of the Kingston area, to confirm the wind directions which they had 'previously determined', and Ex. 37 to determine the relative direction of winds to the bank of the silos. He also considered Ex. 24 which is the report of Dr. Emil Simiu. The latter is an employee of the United States' Federal Government.

From the documents and charts that he reviewed, he determined that the eye of Hurricane Gilbert was about 15 miles in diameter, and the radius of maximum winds from the centre of the eye was about 15 miles. He observed that there was a difference between the wind measured at the Norman Manley International airport and that which would have been measured at the Flour Mill had they been able to measure it. The speed, conservatively, he said, would have been 15% higher at the Flour Mill than at the Norman Manley airport. This is in relation to wind from a northerly direction. The increase in the speed of the wind at the Flour Mill is due to Long Mountain which looks like an upside down boat. The wind flow coming over Kingston has to be diverted around the mountain which is 1,400 feet high and forms a major obstruction to the flow. Ex. 45, [an article in the Journal of Wind Engineering and Industrial Aerodynamics,15 (1983)] gives, he feels, an indication of what would be a reasonable increase in speed.

Flow over mountain ridges has, he said, been studied in detail, but flow around the side of mountains of this size has not received much attention. He would have expected more air being displaced

around Long Mountain than around a shallow or low mountain (as in Ex. 45) because the flow can go over the top very easily. The speed around the silos would have increased more than the case in Ex. 45. The wind load on the silos would come up and go down. The movement would be very small because the building is very stiff. The rate of change of load (wind load, that is) would not significantly affect the behaviour of the structure itself. In relation to the southeast corner particularly, it would have virtually no effect on the structure but it will have an effect on the way the soil responds. The nature of the response by the soil was not an area that he felt he would have been able to comment on as that was a matter for the soil expert.

Professor Sparks said that in their calculations as to wind speeds, pressures, and forces acting on the silos and headhouse, Zetlin-Argo and Dr. Simiu placed more importance on the torque on the bank of the silos than he would have done. The contents of Ex. 18 seem to be word-for-word taken from Ex. 24 (Dr. Simiu's report).

The professor converted the wind speed to pressures and forces acting on the silos and the head house. His analysis, he said, was independent from that which had been done by others. He did this, he said, because he thought it was better for him to do his own work than to follow that of others. He used published data of the effect of the overall forces on structure in terms of the overturning effect of the loads applied to the silo and the headhouse. His next step, he said, was to make an estimate of the soil pressures that would occur as a result of the maximum loads applied to the structure.

Professor Sparks' calculations produced significantly different figures from those calculated by Zetlin-Argo and set out in Fig. G-23 of Ex. 18. In the southwest corner, the professor calculated soil pressures of 2.3 kips per square inch whereas Zetlin-Argo got 1.69; in the northwest corner, he calculated minus 2.76 compared

with minus 1.69 by Zetlin-Argo; in the northeast, he got minus 3.5 compared with 3.7 by Zetlin-Argo; and, finally, in the southeast corner,he got 3.81 compared with 3.77 by Zetlin-Argo. **On the basis of the figures produced by Zetlin-Argo, and using the torque in the correct direction, the worst soil pressure due to Hurricane Gilbert occurred at the southwest corner of the silo bank.** It is important to mention that the distribution formula quoted on sheet G-38 of Ex. 18 and used by Zetlin-Argo is not an equation that the professor had come across before, although he has come across many formulas in his work. In short, it is unknown to him. **However, he (the said professor) used the said unknown formula in arriving at the soil pressures that he gave.**

Professor Sparks' calculations as to the soil pressures were based on the silos being a rectangular block with sharp edges but the professor has said that the block is not rectangular and does not have sharp edges. He in fact said that the silos have curved corners. Engineers, he said,do make a distinction between curved corners and sharp edges. **Like himself, Dr. Zetlin and Dr. Simiu did not take into consideration the fact that the silos have rounded corners.** There is no formula for an engineer to use that fits the exact shape of the structure, so the formula that is nearest to the shape was used.

The witness said that it was quite likely that due to the presence of ancillary buildings near the northwest corner, aerodynamic effects would be somewhat different for the west and east halves of the silos. For this reason, the value of the total wind force and the torsional wind-induced moment would differ from those that would obtain in the absence of the ancillary buildings. These buildings would have a shielding effect, and the witness would imagine that consequently, the wind load in that corner would be reduced. He said that he would probably agree with Dr. Simiu that wind tunnel tests would be necessary to determine accurately the nature of the forces. The forces near the ground, being slower,

have much less effect. There would therefore be less overturning effect on the structure by the wind. Dr.Simiu's report has not included any reductions for this situation; neither has Zetlin-Argo. Some allowance should have been made for the shelter provided by that building.

In Ex.24, at page 6,there are certain factors referred to. The witness said that these factors (for tall buildings with a rectangular shape in the plan) do not take into account the shielding effect of buildings. This is so although those factors are to be reduced if there are buildings providing a shielding effect. The silos are just a big lump; they don't bounce around in such a way that it influences the wind and so the wind loads are lower on the bank of silos because it is big and stiff. It is massive as compared to something which would be very flexible.

Looking at pages 9 and 10 of Ex. 24, paragraph 4.1, dealing with mean torsional moments, taking particular note of the formulae, the witness said that so far as the mean torque is concerned you would expect it to be in an anti-clockwise direction. However, Zetlin-Argo used it in a clockwise direction. The forces on the silos would probably be felt by the entire foundation; the whole structure is connected to the foundation and would probably respond to those fluctuations.

Dr. Issa Oweis

This witness is President of an entity known as Converse Consultants East with its office in Parsipan, New Jersey, U.S.A. He has a Ph.D. in civil engineering from the University of Texas. He acquired this in 1968, and has been since that year a practitioner in civil engineering and technical engineering in the U.S.A.. Since 1984, he has been an adjunct professor at the New Jersey Institute of Technology. There, he teaches soil dynamics and foundation

engineering. In 1991, he was visiting lecturer at Rutgers University, teaching ground water engineering. For the past 25 years, his experience has covered technical engineering practice as related to the design and construction of civil structures such as buildings, highways, tunnels, and dams. He has also concentrated on earthquake engineering and environmental geo-technology with respect to the management of hazardous waste and solid waste. In the area of publications, he has done work on geo-technical engineering practice such as settlements, slope stability, and other matters covering responsibility of structure and soil profile.

In the instant case, Dr. Oweis' task was to predict and evaluate the settlement before and after Hurricane Gilbert. The evaluation would include a determination of the effect of the dead plus grain load on the silos, as well as the effect of the hurricane load on the foundation. The report which was admitted in evidence as Ex. 20, was written by Dr. Oweis and summarizes the settlements under different loading conditions. A non-linear approach was used. The main difference between Dr. Oweis and the defence was in the approach taken - Dr. Oweis favours the non-linear whereas the defence favours the linear approach. Dr. Oweis dismisses the linear approach as irrelevant.

In the initial stage, Dr. Oweis was concerned that the reason for the failure of the silos was mass slope instability. As a result,sloping parameters were put in. Holes were dug in the ground, a special casing was anchored and then by pressure instruments, movements were measured. Piezometers were also put in and monitored. The conclusion was that the slope was stable and that there was no need to worry about mass slope instability.

The next step was the gathering of information to conduct the settlement analysis. It was considered that a finite element

analysis should be done in which borings were done and in addition to the borings, the field data were used. The borings were confined to the eastern side of the silos. The soil profile was divided into layers, and each layer was assigned certain properties. All the parameters were put into a two dimensional finite element nonlinear model; the load given by the structural expert was applied, and then the deformation or settlement calculated. The formula that is on Sheet G-38 of Ex.18 is well-known to Dr. Oweis. The latter was asked by the plaintiff's attorney-at-law to compare the settlements derived from Zetlin-Argo's figures with those from Professor Sparks. The results, he said, were very close to each other and for all practical purposes are the same.

Dr. Oweis concluded that it is possible that the silos or the foundation of the silos may have experienced a pressure above the average dead plus live load; however, for the foundation to experience an excess pressure during the operation equivalent to 3.77 kips per square foot is not possible and for this to happen Gilbert should have occurred before. In his analysis, for the purpose of the settlement analysis, the average loading used is the historic dead load which is the load of concrete plus one hundred percent of the live load. Later, he said he was told that the one hundred percent was really eighty-five percent. The historic loading is the proper weight to use in settlement analysis. The only logical way to calculate settlement is to use the historic average dead plus live load of the facility.

In commenting on the 1993 work of Engineering Geology Limited, Dr. Oweis said that he believes it was done in the right direction. However, he said, the result was disappointing because it did not fit into the physical situation and so the results are wrong and require re-examination.

Engineering Geology Limited had summarized work that it had done earlier, and defined in more detail the ground model used and the

analyses undertaken to estimate the settlement of the subsoils under the loads imposed by the silo bins and the wind from Hurricane Gilbert .

In his analysis, Dr. Oweis assumed that there was uniformity of loading of the silos in the initial stages of the life of the silos, and that there was no question of any tilt then. So far as giving consideration to the tunnel and the headhouse, Dr. Oweis regards this as a matter of refinement. In answer to a general question by the Court, Dr. Oweis agreed that engineers do not assign the same level of importance to everything; some may downplay certain areas and matters that others consider important.

In many cases, in his practice, Dr. Oweis takes the total load and computes the pressures to estimate the settlement. In the instant case, however, he was given the pressures to predict the settlement. The engineering judgment of Mr. Cader intervened between the loads and the settlements that were eventually arrived at.

Although Dr. Oweis was required in his evaluation to determine the effect of the dead plus grain load on the silos, and the effect of the hurricane on the foundation, he told the Court that it would not have mattered if the silos were empty or had air in them because the soil had already settled before the hurricane. The wind force on the empty silos would have been the same as on the full silos because the soil had already settled. Notwithstanding this evidence from Dr. Oweis, he maintained that more load causes more settlement.

In the instant case, Dr. Oweis confirmed that nobody had ever measured the footprint. Measurement of footprint is theoretically possible, he said. However, engineers are necessary to interpret it. Much depends on the engineer's assessment and also on the

unacceptable when one applies the appropriate standard of proof. The defence was not satisfied to merely challenge the plaintiff's case with a view to destroying it. They went beyond that effort and called two witnesses, hoping that their expert opinion as to the cause of the collapse would gain the favour of the Court. The witnesses were Mr. Basil Minor and Professor Denis Mitchell. There is no doubt that their evidence was very important. The strong view expressed by and on behalf of the defence was that the collapse was due to faulty design and construction of the silos, made worse by non-inspection and non-maintenance of the facility in critical areas.

Mr, Basil Minor

This witness is a civil engineer who obtained an honours degree at Cambridge University, England, in 1963. He holds the Master of Arts degree from that university (M.A.Cantab.). He has been a member of the Institution of Civil Engineers in the United Kingdom since 1970. Mr. Minor is a chartered engineer and, since 1978, he has been an Associate of Norman and Dawbarn, a firm of architects and consulting engineers. He specializes in the field of buildings and structures as opposed to say water works or highways, although he has worked in those areas. He has worked in Malta for six months, in various countries of Africa for seven years, and in the United Kingdom for the rest of his professional life so far. His work has included work on bridges and silos. In the United Kingdom, he has worked on two sets of silos-- one set of two silos in Bristol which had a capacity of 20,000 tons each, and the other, a set of four, in London with a capacity of 10,000 tons each. In the first case, they were engaged in converting two liquid ammonia tanks into cement silos; in the second, they built a set of silos in reinforced concrete for a cement company. The first time that he came into contact with silos was as a result of a failure of a flour bin. This was in Zambia.

In the instant case, Mr. Minor examined the silos one week after the collapse. Having done so, he produced reports on the features of the collapse. These are to be found in Exhibits 26, 27, 28, 29, and 30. These reports were produced in conjunction with Messrs. R. B. Hawkins and Associates who had originally been instructed by the defence to conduct the investigations into the collapse. This latter firm is well known in the United Kingdom so far as the investigation of arson and explosions is concerned. Initially there had been the thinking that the collapse would have involved this area of expertise. Messrs R.B.Dawkins and Associates thought it prudent to have a structural engineering expert with them, and that accounts for the invitation to Mr. Minor and the involvement of Messrs Norman and Dawbarn thereafter.

The main portion of the report that is marked Exhibit 26 was written by Mr. Peter Pugh of R. B. Hawkins and Associates who accompanied Mr. Minor to the site. There is attached to that report an appendix marked Appendix 1. That was written by Mr. Minor. On the last page of that appendix, the following is recorded:

"The normal forces on the silo walls due to grain were sufficient to cause failure of the structure. Over a period of weeks, months or years the bond between the concrete and the steel reinforcement has been reducing. At some stage this probably led to the complete failure of one or two of the bars anchored across the final rupture plane. The migration of the stresses from the now useless anchors at the next loading cycle to those next above and below, resulted in these failing as well and the wall between Silos 10 and 18 opening up from bottom to top as if unzipped. From this primary failure all other damage was inevitable."

According to Mr. Minor, that view which was recorded on the first day of November, 1988, and which had been formed before that date, has not been changed. There has been no alteration or modification

as a result of the subsequent calculations, reports, and computer studies.

Mr. Miñor explained the failure in this way:

"The bins are subject to be filled and emptied with grain; that is, after all its purpose. They are repositories of grain, to store grain between the time it arrives...until it is wanted. The purpose therefore of the silos is to act as a buffer to hold the storage of grain for a period of time and then to be extracted, therefore, it is normal that grain goes into the silos to be taken out...and this will happen regularly throughout the years.... The grain in filling the silos exert pressures ...on surfaces on which it is in contact... The weight of grain is not solely taken on the floor, it is also taken on the walls. If you can imagine a paper bag, you fill it with rice, sugar, or with grain; the paper bag doesn't retain its square shape, it goes outwards because the sugar or flour or whatever .... pushes sideways as well as pushing down on the bottom, it is that pressure which silo walls have to be designed for. The silo wall is designed for pressure to go downwards due to the weight of the grain. The silo walls have to be designed for the outward pressure exerted by grain whereas the floor has to be designed for the downward pressure due to grain."

Mr. Minor continued:

"...because the grain is pushing outward and.....is in contact with "the wall there is friction between the grain and the wall, and the grain cant go down because that friction stops the grain from sliding downwards, therefore a very high proportion of the total weight of the grain is taken by the friction on the wall, down the walls into the foundation. This means the walls are carrying a very high proportion of the weight of the grain in the silo..... This puts the walls of the silos vertically into compression. So the walls of the silos are being pushed downward both because of the

self-weight and the weight of the grain in them. So the vertical stress is compressive in a silo under normal operating conditions. The horizontal stress however because grain is trying to push sideways is tension and which is called hoop tension."

Mr. Minor went on to refer to a formula known as Janssen's formula which determines the pressure within a granular material inside a silo. It quantifies the outward forces caused by granular materials in a cylindrical silo. This formula operates when a silo is being filled or when it is in a static state. However, it was found, due to a number of grain silo failures, that higher stresses are in fact obtained when silos are being emptied. The Janssen formula has been known since 1895.

Mr. Minor examined the nature of the reinforcement and concluded that it appeared to be mild steel of a quality that was in excess of that required by the drawings. As far as he is aware, the quality of the steel had nothing to do with the collapse of the silos as no steel was shown to have broken during the collapse. There seemed to have been very little protrusion of reinforcing bars out of the concrete at the point of the collapse. After he had seen the drawings, Mr. Minor did a survey of the number of bars that protruded out of the concrete and the manner of the protrusion. He and Mr. Pugh took photographs of the disaster and these are fully visible in Exhibit 27.

In view of what he saw, Mr. Minor expressed the following lengthy opinion:

"During the loading/unloading over months, over the years the bins have been subjected to stresses; they are being loaded on one side and loaded on the other side, unloaded on one side, unloaded on the other side. The crack perhaps might have been there from the very beginning - or perhaps the crack occurred in the first filling or second filling, small cracks, slowly open under each successive

filling or second filling and emptying; when one bin is full it puts bending moment into the partition. In some areas some bending moment would be positive, in some areas some would be negative, that is,if bin 'A' was full, if on the other hand bin 'B' is full, bin 'A' is empty then moments occur in the same wall, but where in one case the moment had produced tension force in one face at that same point it would now produce compressive stresses. So if filling bin 'A' cracks, filling bin 'B' is likely to close the crack. When bin 'A' is filled again that same crack is then back in a state of stress. The crack itself cannot take any tension so the tensile stresses have to go around the crack and it produces above and below the crack, tips of crack, a higher stress than average.....but the stress cannot go across the crack, so that stress has to flow around the crack which means that the average stress just above the crack is higher than that which is throughout the wall.".

Mr. Minor continued by saying that as the crack opens it eases tension across that crack in the act of opening. The cracks get larger, and eventually there is a point that is arrived at where there is too much crack and one is relying no longer on the stresses being distributed both by the concrete and the steel reinforcement, but all the stress must be taken by the reinforcement. As noted earlier, the reinforcement is the bars. What then has to be determined is whether the bars themselves are properly bonded into the concrete for them to transfer stress from one reinforcing bar to the another. If there are not enough bars, the stresses in the bars would be too high and the bars would break. In the silos as seen by Mr. Minor, there were no lapping bars. As a result, he is of the opinion that the design (which did not call for 'lap length') was very bad in this respect. It should be noted that the Code of Practice required it.

Mr. Minor made a record of the first sixty layers of bars. He observed that fifty percent of the bars did not go around the jacking rod. That in his view was very poor construction. There is a distance of about nine inches between the layers. He noted further that some of the bars had rusted. The degree of rusting was not in his opinion consistent with a time span of two or three weeks; it was more consistent with a time span of years. In this regard, he made specific reference to photograph no.36 from Exhibit 27.

Tests conducted on behalf of the defendants indicated that the water/cement ratio was very high so far as the concrete is concerned. It seemed that water had been added to portions of the concrete after the concrete had been poured. That, in the opinion of Mr. Minor, was a cardinal sin in concrete construction.

In relation to the computer runs done by Zetlin-Argo, Mr. Minor was very critical of them. Firstly, the size of the elements chosen was too large. Secondly, a lot of the silo bank seemed to have been missing as there were only seven silos used whereas there were twenty-two. Thirdly, there were no floors, no tunnel, no elevator pit. The loading of the silos seemed to have had no connection with reality. Finally, the boundary conditions bore no relevance to conditions at the site and in fact some were clearly wrong.

The challenge relating to the Zetlin-Argo computer runs is set out in Exhibit 29. Mr. Minor, in conjunction with Strucom Structures and Computers Ltd., created his own computer models. The result was that he was convinced that it was exceedingly difficult, if not impossible, to get the differential settlement reported by Zetlin-Argo; further, had there been a settlement, whatever its value, the higher stresses would have occurred elsewhere in the silos than in the area that collapsed. Exhibit 29 amounts to an examination of some of the statements and hypotheses put forward by Zetlin-Argo in

their final report. However, as a result of evidence given by Mr. Cader at the trial, and in an apparent effort to cover every area of the case presented by the plaintiff (imagined or real), the defence through Mr. Minor produced Exhibit 57. This is a report on the foundation pressures caused by the hurricane wind loads as defined by Mr. Cader in his evidence in March, 1993. Further in Exhibit 57A, there is an analysis carried out by Strucom to model the effect of grain loading and wind loading only on the soil strata underneath the silo bank. The intention behind Exhibit 57 was that of seeing what would happen if the wind came from the northwest, and Strucom applied that to the actual grain on the day of the hurricane. It shows that with four different foundation conditions "that the soil properties, the set of soil properties, pressure is higher or was higher on the day of the hurricane in the southwest than it was in the southeast.". It also shows that the soil pressure distributions are not as given by Zetlin-Argo, Professor Sparks or Mr. Cader. In Mr. Minor's opinion, if the soil pressures in the southwest are higher than they are in the southeast on the day of the hurricane under the worse wind load, then clearly there could not have been a differential pressure towards the southeast caused by the hurricane. If there had been any differential pressure caused by the hurricane, (and he is not accepting that there was such a thing) then it must surely have been towards the southwest. If, he said, there is no differential settlement or there is a differential settlement to the southwest then the sole theory of locked in stresses produced by Zetlin-Argo is clearly erroneous.

The overall position of Mr. Minor is that the defence has done a more thorough computer analysis than the plaintiff, as the former has considered all the different effects the foundation conditions would have. Zetlin-Argo came to a decision first and then attempted to work towards that decision. Zetlin-Argo also attempted to use average grain loads whereas the defence used the actual grain

loads. Exhibit 17 which was produced by the plaintiff does not show any input for the distribution of grain on the day of the hurricane or the day of the collapse; nor is there any input for wind or grain on the day of the hurricane or the day of the collapse. In Mr. Minor's opinion, Exhibit 17 and the other computer runs prior to it have no relevance to the circumstances of the case.

Mr. Minor did his own calculations too. He was trying to determine the sort of order of magnitude of stresses that he would find in the silos due to grain, wind, hurricane, and earthquake. His calculations led him to conclude, in part,that the wind load itself never put any stresses in the silo at any point in an area where there was a likelihood of failure occurring; and stresses due to wind load, hurricane intensity, was a mere fraction of the stresses due to grain "and that was just typical grain, it wasn't a particularly high granule and therefore the hurricane itself caused no damage to the silo - none whatsoever.".

According to Mr. Minor, the wind calculations by Dr. Simiu and Dr. Zetlin were flawed; so too were the soil pressures calculated by Dr. Zetlin. The manner in which Mr. Cader converted the wind load into soil pressure was also wrong.

Like Mr. Cader, Mr. Minor would not have designed the silos as had been done. His reason was in relation to the distribution of concrete and steel within the silos. In his opinion, the only proper way to transfer stress from one reinforcing bar to another is for those two bars to be in close proximity to each other over a length called a lap length, or be spliced. As he saw it, the design as shown on the drawings shows no overlap other than some hooks around a vertical bar. He is not happy with the actual location of some of the bars; nor with the lack of bars in some areas. The Code, he said, requires the staggering of every three set of bars. The consequence of staggering is that if there is failure of one overlap, all would not fail together.

It is Mr. Minor's opinion that the structure was inadequately provided with reinforcement in so far as the location of such reinforcement was concerned, and probably in relation to the amount thereof. This under-provision of reinforcement resulted in cracking occurring at discrete points in the walls. In his conclusion in Exhibit 28, Mr. Minor states:

"We have checked the effects of the recent hurricane and of earthquakes since the silo block was built. We have also had some samples of the materials of which the silo was built, tested. The results of these further deliberations has been to confirm in us our initial opinion that they had no bearing on the cause of failure and that the collapse was due to poor detailing of the reinforcement in a critical joint aggravated by poor construction. As this, and other similar poor details, are common throughout the structure, we do not think that the silos should be filled again, unless they are strengthened and the design checked against up-to-date internationally recognized codes of practice.".

It is to be noted that Mr. Cader, during examination-in-chief, said that in 1990 remedial work was done to the silos. Additional reinforcement was provided to bring the bins in line with the requirements of the 1988 Code. They took into account the dynamic effect of the grain pressure. The soil was also reinforced by injecting it with a view to protect against future hurricanes as strong as Gilbert or stronger.

Mr. Minor on the tilt

The fact that a structure is not built vertically " is absolutely normal. Any building that is vertical is the exception. It is a matter of the degree that it is not built vertical; some are closer to vertical than others.".

Assuming that there is a tilt, Mr. Minor is saying that there is nothing to indicate that it was caused by settlement; and nothing to indicate whether that settlement occurred in the twenty years before Gilbert, during Gilbert, or in the two weeks after Gilbert. The indication, he says, is that the tilt was not caused by Gilbert because on the day of Gilbert there was more grain towards the southwest than there was towards the southeast. Therefore the centre of gravity of the load was towards the south west, and not towards the southeast.

In order to determine whether there has been a tilt due to settlement, one needs two references for the purpose of measurement. Two references are needed, that is, before and after a particular incident in order to say whether or when a tilt occurred-- if it is due to settlement. There is no evidence, he says, as to what the actual settlements were before and after Gilbert or as to what the actual tilts were before and after Gilbert.

Retention of forces within the silos

In an apparent reference to paragraph 10 of the statement, and to what I have in this judgment referred to as the issue for determination, Mr. Minor said in cross-examination that he was unable to find a mechanism by which forces exerted by the hurricane could have been retained within the structure, that is, the silos, over a period of fourteen days, so that they could have worked together with the stresses that were caused by the loading on the day of the collapse.

Professor Denis Mitchell

The final witness called in this case was Professor Denis Mitchell. His curriculum vitae occupied all of sixteen type-written pages. The evidence of this witness took on added significance, it seemed,

on October 21, 1993, when a few moments before the adjournment, learned Queen's Counsel, Mr. Mahfood, stated that Exhibit 40 (Mitchell's Report) was one hundred percent in his (plaintiff's) corner.

Dr. Mitchell is Professor of Engineering in the Department of Civil Engineering and Applied Mechanics at McGill University in Canada. He has been such since 1986. He holds a degree of B.A.Sc.(Toronto) (honours graduate,1969) an M.A.Sc.(Toronto)(1971),and a Ph.D.(Toronto)(1974), all in engineering. He is also Professional Engineer in the Order of Engineers of Quebec; a member of the Engineering Institute of Canada; a Fellow of the Canadian Society for Civil Engineering; a Fellow of the American Concrete Institute; member of the Pre-stressed Concrete Institute; member of the American Society of Civil Engineers, and a member of the Earthquake Engineering Research Institute. He has been a member of the American Concrete Institute Technical Committee 408-Development of Reinforcement from 1974 to the present time. At this moment, he is the chairman of the committee. He has, needless to say, published several books and papers in keeping with his area of expertise.

Professor Mitchell is not a stranger to the investigation of the failure of structures; nor is he a stranger so far as giving evidence is concerned. He has investigated failures in several countries on behalf of the Government of Canada.

In the instant case, he was asked to investigate the adequacy of the hook anchorage details in the silos. For that purpose, he was provided with two structural drawings which showed the details of the anchorage. He was also provided with copies of photographs that had been included in Mr. Minor's reports.

With the help of Dr. William D. Cook, a research engineer at McGill University, Professor Mitchell carried out the investigation and

made a report which was admitted in evidence as Exhibit 40. In order to investigate the performance of the hooked anchorage details used in the silos, a series of tension specimens and a series of bending specimens were constructed and tested. "The purpose of the tension specimens was to investigate the basic bond characteristics of the different types of hooked anchorage details present in the silo..... The purpose of the bending specimens was to investigate the performance of the different types of hooked anchorage details when the silo walls are subjected to bending". In addition, the performance of these specimens was compared with the performance of those specimens that contain lap-spliced reinforcing bars.

Professor Mitchell found that the reinforcement details in the drawings were inappropriate "simply because the reinforcing bars have to deliver tension along the length of the straight wall and transfer the tension. The reinforcing bars must carry tension because concrete is extremely weak.....and unreliable in tension and so reinforcing bars must transmit the tension from the straight wall portion to both curved portions of the wall and so they must carry that tension through the walls." In order to do this, one should lap the bars to transfer the tension directly in the reinforcement. Splicing was necessary in the instant case, and a prudent engineer would have staggered the splices. This staggering would prevent there being a single plane of weakness. It is bad detailing to hook bars all at one location. The staggering would involve alternating the splices. There are textbooks from the 1950s and early 1960s that recommend lapped splices in addition to having hooks at the end of bars. That was the thinking that ought to have guided practitioners at the time the silos were built.

Having stated the need for proper splicing and staggering, Professor Mitchell gave an opinion as to the strength in tension of one foot of silo wall if there had been proper splicing and

staggering. He said that the strength was 64.55 kips which is considerably more than the 44.84 kips that Zetlin-Argo said was the force that was applied to the structure. The Zetlin-Argo estimated force would in the circumstances have caused the concrete to crack, but there would have been no failure or collapse.

On the basis of the photographs that Professor Mitchell saw, as well as his reading of Exhibit 15, he was of the view that the concrete was pre-cracked quite severely, as there were many old cracks and the silos, he reminded us, had poor concrete quality and were subjected to reverse cyclic loading.

In the opinion of Professor Mitchell, the hooks as detailed were really no adequate substitute for splicing. Furthermore, the hooks as detailed in the drawings were barely overlapping, and this caused a point of high concentration of tensile stress in the concrete in the haunch. This situation could cause premature collapse or failure in that section. He calculated that the hooks were seventy-seven to eighty percent effective.

ASSESSMENT OF THE WITNESSES AND FINDINGS

The witnesses had excellent academic qualifications and, apparently, good professional standing. This surely may be regarded as one of the most technical cases to have been heard in our Courts. Although there is no doubt as to the technical nature of the case, bearing in mind the calculations, computer runs, and the general use and application of engineering terms and principles, the issue is still a matter of fact, as most cases are. In view of the sharp differences that have surfaced between the engineers called by the plaintiff and those called by the defendants, the Court has had to assess even these great minds for credibility, relevance and accuracy, among other things. Both sides cannot be correct, as I understand the positions that have been put forward.

The witnesses, with the exception of Messrs Calvin Gray (meteorologist) and John Lee (accountant) were in the witness box for long periods. They were examined in detail, and were cross-examined on everything that was in question. Sometimes they were also cross-examined on matters that were not in dispute. In the case of Messrs. Cader and Minor, there were times when the Court wondered whether the end would have come during this decade. That is not to say that the proceedings were not interesting. Indeed, for most of the time, they were gripping. The extended stay of the witnesses in the witness box gave the Court more than ample opportunity, I should think, to properly assess their demeanour and to ultimately be in a position to say whether their evidence can be relied on or not.

In assessing the witnesses, and making my findings of fact, I bear in mind the standard of proof in a case of this nature-- the balance of probabilities.

WITNESSES CALLED BY THE PLAINTIFF

Mr. Cader occupied the witness box for what may be described as a considerable time. He was cleverly and closely cross-examined. During that time, he stated that he was not an expert in concrete technology; neither was he an expert in the field of mechanics; nor was he a wind expert; and, finally, he said that he was not a soil expert. Notwithstanding these statements by the witness, it cannot properly be left unsaid that it seemed to the Court that he had far more than a basic grasp of the various subject areas. It did not seem to the Court that he had been put forward by the plaintiff merely to deal with the calculations and the computer runs. It seems that he was put forward by virtue of his apparently vast experience, and his expertise and skill as a structural engineer. Indeed, the Court formed the impression that he was presented as the allrounder on the plaintiff's team.

Mr. Cader had an unenviable task. With Dr. Zetlin no longer available, it fell to Mr. Cader, it seemed, to carry the burden of the Zetlin-Argo reports. The significance of his position and his role was not, and could not have been, lost on him. He appreciated to the fullest extent, it seemed, that which was expected of him, if the plaintiff were to succeed in its claim.

The Court made a careful note of Mr. Cader's generally calm attitude even under the most vigorous and piercing cross-examination. This was a feature that was, in the opinion of the Court, contrary to his stated lack of experience as a witness. It is noteworthy that he refused the offer of a seat during the entire time that he was in the witness box. He was most courteous in most of his replies and reactions even when pushed to the brink by teasing cross-examination. He certainly cannot be faulted on this score. In terms of behaviour, he may well be classified as a model witness. Although English is not his native tongue, he demonstrated good command of the language, notwithstanding his apparent attempt at times to give a different impression.

In assessing the demeanour of Mr. Cader, I could not help observing with some degree of concern the bouts of stammering and stuttering that seized him occasionally during the trial. They occurred during cross-examination. There were two particular moments that commanded me to make an appropriate note. Those were on the 24th March and the 10th May, 1993. On both occasions, we were in the post-lunch session. Mr. Cader was being cross-examined in relation to the computer runs, and was clearly most uncomfortable. I am not aware of anything other than the content of the cross-examination that could have been bothering him. That he was suffering great discomfort was obvious. It did not seem to have been of a medical nature as he most certainly would have mentioned it. In my judgment, his thought processes were under severe pressure due to the situation in which he thought the plaintiff had found itself on the issue of the moment.

On the 24th March, he was cross-examined in relation to Exhibit 18 page 21 of the section marked S and dealing with input. This is a portion of what occurred:

Question: Now, do I understand... that you used a multiplier of minus 5?

Answer : Yes...

Question: Tell me if this is what you did. You thought of a figure you took a figure out of the air, and you used it as a multiplier?

Answer : Not quite so, sir.

Question: Almost?

Answer : No, no, it was the representation of a certain part of the dead load which was not included and the partial live load..

Question: Could you say that again?

Answer : This load condition represents the dead load and partial live load, so in this particular multiplier it covers the additional weight of the structure which was not included in the model like the foundation mat under the sub grade structure, the head house and the roof plus the partial live load.

Question: So you first of all used your dead load, and you sort of said, well, the thing I forgot to use let me take an omnibus figure to represent them?

Answer : No, no. it was the certain load condition which later was more defined to bring the structure to deformation which we were expecting as..

Question: The deformation that you intended to find?

Answer : Right.

Question: I see. So you set out with a particular end in view, to achieve a particular result and you adapted your figures to achieve that result?

Answer : Maybe it is not the right description of what I have done. I assumed certain load conditions and with the

boundary condition which we had chosen for the structure we simulated it by those two components.

Question: Which are those?

Answer : The load and boundary conditions.

Question: Which load?

Answer : This vertical load with the minus five multiplier.

Question: The dead load?

Answer : Dead load plus partial live load.

Question: What you mean by partial live load?

Answer : Not a full hundred percent.

Question: How partial is partial?

Answer : In this case it was probably about 40%.

.....

Question: Mr. Cader, you mean you just made a guess and say five times should do it?

Answer : This is the engineering method called iteration. I don't know if you have heard of that. This is the method where you approach the problem by trying different conditions of the structure to find out the final deformation in our case.

In answer to a question by the Court, Mr. Cader continued in his description of the method by saying:

Answer : Yes, when there are too many variables which is almost impossible to resolve mathematically, we use the method by calculating step by step looking if the numbers are getting closer.

Question: To what you want?

Answer : To what I was looking for.

Question: To what you are trying to find?

Answer : It was clear that I was trying to find a deformation which complied with the differential settlement, it was not hidden. I don't want to make the impression that it was a guess work; it was quite an accurate direction which I was going by using the computer analysis.

Under further relevant cross-examination by the defence in relation to his distribution of the load in his computer run, the following is recorded:

Question: That's what you were trying to find, Mr. Cader?

Answer : That's exactly what I had done, I tried to find the differential settlement...

Question: So although you know that there was not an even distribution of the load in the silos you nevertheless went ahead and did your calculations.. commanded your computer to do as if there had been an equal distribution in the silos?

Answer : YES.

The significance of the passages that I have just quoted will be readily appreciated when it is considered that the differential settlement forms a key aspect of the plaintiff's case. Without it, there is no tilt !!

On the 10th May, this interesting exchange took place between Mr.Cader and learned Queen's Counsel, Mr. George, who conducted the cross-examination.

Question: Mr. Cader, how can you justify- in all seriousness, how can you justify your input by the results of your output? I mean, surely....

Answer : That is the way we often work in engineering.

No useful purpose would be served by quoting at this stage further passages from the evidence. The record speaks for itself. On both dates referred to, the effects that I observed in the afternoon sessions seemed to have flowed from the build-up in the cross-examination in the morning sessions ending with what I regard as damning and damaging admissions by Mr. Cader. It is clear that Mr. Cader never expected nor anticipated that there would have been such probing of the computer runs.

On the 12th May, there was further cross-examination on the computer runs. On this occasion, dealing with the fourth run,Mr. Cader said that the method of iteration was not quite the same as trial and error. However, he agreed that it was trial and failure, and not coming up to scratch in a broad sense. When asked if it would not have been simpler, less time consuming, and more accurate to put in the "things as they are rather than fudging around with trial and failure and try and try, and iteration and repetition", Mr. Cader replied in the negative. I recall the expression on his face when he gave this response. He clearly did not intend that the Court should have regarded that answer as an honest one. He was merely defending a position which he thought required some degree of protection.

There was a general reluctance on the part of Mr. Cader to admit the obvious where he seemed to have been of the view that such admission would hurt the plaintiff's case. That makes his stammering and stuttering on the dates aforementioned even more significant, as it is clear that he had no alternative then but to yield ground to the cross-examiner.

Earlier, on the 17th February, Mr. Cader was cross-examined in relation to the strength of the concrete in the silos. He said that the tests revealed that there was honeycomb in the concrete. This he said would have brought down the value of the concrete; further, if concrete is going to crack, it generally cracks at its weakest point. Now, it is well known that the haunch is the crucial area in the case. The strength of the haunch is in question. The strength of the concrete in that area is therefore of some importance. Mr. Cader testified that there was no honeycomb in the haunch; that he had personally checked it as far as he could. However, he did not include that fact in any of the numerous reports prepared on behalf of the plaintiff. I have not been able to come up with any rational explanation for Mr. Cader's exclusion of the absence of honeycomb

in that vital area from his reports, other than that he was not speaking the truth when he said that there was no honeycomb in the haunch. He obviously felt that such an admission would have been too big a blow to inflict on the plaintiff's case. The Court could not help further observing his extreme reluctance to put a percentage figure for depreciation in the strength of the concrete given the presence of the honeycomb, cold joints and delaminations. It may well be asked whether truth was being sacrificed in the interests of the plaintiff, as Mr. Cader saw it. Having asked that question, my judgment tells me that the answer is in the affirmative.

The presence of honeycomb was not the only matter that was excluded from the reports, according to Mr. Cader. Earlier in evidence on the said 17th February, Mr. Cader had mentioned a conclusion that had been arrived at by him and his team on a visit to the silos. When challenged as to the basis for the conclusion, he said that it was supported by "certain engineering calculations" that they had done during the short period of time. When he was further pressed, he admitted that those calculations were not in any of the reports.

The general reluctance of Mr. Cader to answer simple questions on what I think he regarded as crucial areas of the plaintiff's case has done severe damage, in my judgment, to his credibility. I formed the impression that he only conceded to the defence when he thought he had no alternative. Let us look at this example:

Question : But you agree with me that the crack took place in a continuous piece of concrete for this case, the crack took place in a continuous piece of concrete?

Answer : Is it a question?

Question : Yes, it is a question. Do you agree with me that the crack took place in a continuous piece of concrete and not at the end of a beam or slab?

Answer : I don't understand the question.

Question : All right, I will put it again. Do you agree with me that the relevant crack in this case took place in a continuous piece of concrete and not at the end of a beam or slab?

Answer : Yes.

This simple question took Mr. Cader so long to answer; much longer than the narrative discloses. The reason is simple. Bond strength was being considered at the time, and Mr. Cader himself is on record later in the proceedings as saying that when bond strength is insufficient, there would be slipping. It is not without some significance that Mr. Mahfood, learned Queen's Counsel, in his opening of the plaintiff's case, had noted that there was going to be a lot of argument about bond strength because of the position adopted by the defence.

The case is replete with instances of situations where Mr. Cader indulged in dodging, mental gymnastics, and plain avoidance of questions. There would be no end to this judgment if the Court was to refer to even one third of such situations. His evidence on the 22nd February dealing particularly with the cement/water ratio demonstrated how painful it was at times to extract an answer from Mr. Cader on a simple matter. His evidence on the 9th March in relation to wind load and on the 10th May in relation to boundary conditions demonstrated, in my judgment, a technique of dodging and avoidance which left the Court with the impression that Mr. Cader was calmly insulting the thought processes of those who were listening to him. I found this outrageous on the part of one who was the key witness in the case.

Quite apart from being reluctant to admit anything suspected by him to be detrimental to the plaintiff's case, Mr. Cader did not hesitate at times to blatantly change his evidence without blinking an eye. Here again, it may be unwise to burden this judgment with

a list of such instances. One that readily comes to mind was the changing of his testimony in relation to the cracking of concrete at its weakest point. This may be noted by comparing his evidence on the 17th February with that of the 24th March. Although the plaintiff had months to explain the reason for this change, the trial ended without any effort being made to assist the Court in this respect.

Mr. Cader admitted errors and shortcomings in his calculations and computer runs. His evidence is replete with such admissions in crucial areas of the case. When I consider these admissions along with his demeanour, I am forced to ponder what other undisclosed or undetected errors and shortcomings there may have been. In addition, as the trial progressed I became very uneasy with the frequency with which he resorted to his " engineering judgment". Indeed, on reflection, he seemed to have regarded his "engineering judgment" as a sort of haven into which he could escape from the challenge of the moment.

Professor Sparks sparked a spirited discussion between the parties as to the propriety and value of his evidence. His presence in the witness box livened the proceedings somewhat as at times he appeared anxious and eager to do verbal battle with learned Queen's Counsel, Mr. Chin See, who cross-examined him.

The plaintiff, through learned Queen's Counsel, Mr. Mahfood, put forward Professor Sparks as a " supportive" witness. The professor came into the picture at the last moment. He wished to demonstrate his independent mind, it seemed. He reviewed the various relevant reports, and did his own conversion of wind speed to pressures and forces acting on the silos and headhouse. His next move was to estimate the soil pressures that would occur as a result of the application of maximum loads to the structure. The result was, as I mentioned earlier, a different set of soil pressures at the four corners of the silos from those advanced in the Zetlin-Argo and

Simiu reports.

Having taken time to consider the situation, I am quite puzzled as to what it is that the plaintiff had hoped to have achieved by calling Professor Sparks. He has certainly not helped the plaintiff's case. He has merely created unexplained and unexplainable contradictions in the plaintiff's case, and has pointed to at least two areas where the plaintiff's other experts have made errors. Here, I am referring to the incorrect equation that was used in Exhibit 29 and to the mean torque which should have been in an anti-clockwise direction but was calculated by Zetlin-Argo in a clockwise direction. Further, Professor Sparks did not do the plaintiff's case any good when he told the Court that he did calculations on the basis of a shape that the silos did not have; **in addition, he used a formula that he did not know to assist him in determining the distribution of stresses, and in arriving at the soil pressures that he gave.** He was clearly a witness on whom I could not rely so far as proof of the plaintiff's case is concerned. Why would a learned professor use a formula that he does not know to arrive at figures that are of vital importance to the plaintiff's case? The answer must be that he wished to deceive the Court!!

The reliability of the professor as a witness was not enhanced, I should add, when consideration is given to his evidence on the presence of the building in the vicinity of the silos lowering the overall forces. On the 15th March, he said that the shielding effect of the building would be about 10%. His words were : "..20% is too high, 10% might be reasonable, but it is certainly not 20% because there was a lot of fallacy.". Shortly after that, the adjournment was taken. On resumption the following day, the learned professor indicated that he had made an error. He informed the Court that the 10% was much too high, and that he would estimate no more than 3% "because the wind.. would leak around the side of the building and create very little pressure". He went on to say this:

"..the presence of the building in fact would tend to trap the air in the corner. So the additional effect is not to reduce the overall load on the building but in fact to increase it." This, to my mind, was a complete about turn by the witness. It was, in my view, brought about not by any engineering fact or theory as discerned by the learned professor but out of a desire to keep the plaintiff's flag flying. I refuse to believe that the learned professor could have made such an error. He simply returned on the morning of the 16th and gave what he must have known was a worthless opinion.

Dr. Issa Oweis is quite familiar with the courtrooms of the United States of America as he spends five percent of his working time giving evidence in that jurisdiction. To say he displayed arrogance is an understatement. That fact does not detract from him as a witness as arrogance may well be a virtue in some. However, in addition, Dr. Oweis was rude in his behaviour and responses to learned attorney-at-law for the defence, Mr. Vassell. I found it necessary to look behind his rudeness seeing that his evidence, on the face of it, ought to have been a simple matter. I concluded that Dr. Oweis came to give evidence in one direction only regardless of the questions; and to crudely rebuff anyone who would wish to prevent him from having his way. I found him clearly insincere and dishonest in several of his responses, and as a result I would be most uncomfortable in relying on his word.

Dr. Oweis' evidence under cross-examination during the afternoon of June 1,1993, is in my view, a classic example of the qualities that I have just noted that I found in him. He was there being cross-examined on the question of "footprint". He pretended that he didn't know what was meant by "footprint" as spoken by Mr. Vassell; nor did he know what was meant by "settlement footprint". He didn't know what Mr. Vassell meant by "direction"; nor did he know

what he meant by "depth". There is a similar trend in his responses for that entire afternoon. During the morning session, he had been no less insincere in his answers relating to "loads". His answers on the following day on the question of "stiffness" were also in the same insincere vein.

In his practice, it is customary for Dr. Oweis to take the total load and compute the pressures to estimate the settlement. In the instant case, for reasons that have not been stated so far as I can recall, Dr. Oweis was given the pressures to predict the settlement. So, it may be said that he started off on an unaccustomed footing. He did something else which was unusual, it would seem. According to him, he used the pressures represented at sheet G 39 of Exhibit 18 by ignoring them. I have not been able to understand how this distinguished engineer managed to use something like pressures by ignoring them.

Dr. Oweis, as indicated in the earlier paragraph, is accustomed to using the total load to compute the pressures and estimate the settlement. "Load", in the engineering world, includes wind load. Dr. Oweis was not bold enough to deny that. However, when learned attorney-at-law, Mr. Vassell asked him whether it was possible to have a wind load at the southeast but none at the southwest, he answered that he was not a wind expert so he could not answer the question. If ever there was a dishonest response, that seemed to me to have been one. It was obvious to me that Dr. Oweis was conscious of the importance of the southeast and the southwest to the case for the plaintiff, and he was not prepared to give any response which might have been unfavourable to the plaintiff.

It seems to me that, overall, Dr. Oweis has seriously compromised his professional standing by some of his statements to the Court. Quite apart from what has been noted so far, the Court has to mention some other examples. He is on record as saying that whatever the actual grain load, it would have had no effect on the

settlement determined by him as the soil had already settled before Gilbert. Yet, he agreed that more load causes more settlement. He also said that it wouldn't have mattered if the silos were empty or had air in them as the soil had settled before Gilbert. The wind force, he would have the Court believe, would be the same on empty silos as on full ones as he said that the soil had already settled.

I found Dr. Oweis' answers, generally, rather instructive when I reflected on the fact that he is supposedly the holder of a Ph.D. and has been a university lecturer and professor. The Court hopes that he has made a more favourable impression on his students and, indeed, on the judicial tribunals of the United States than he has made while giving evidence in this case.

WITNESSES FOR THE DEFENCE

I was impressed by the technical knowledge and expertise of Mr. Minor in particular. By the time he came to give his evidence, the Court had become quite familiar with the engineering details that had been the subject of evidence during the previous months. The clarity of his expressions made for a greater understanding of the technicalities of the case. His was not a partisan stance. He was obviously committed to truth. He clearly has a brilliant mind coupled with a great gift of being able to impart his knowledge in an uncomplicated manner without seeming to stoop to do so.

The Court cannot ignore the fact that Mr. Minor was the only witness who had had the privilege of actually working as an engineer in relation to silos prior to this case. That he worked in several countries in this area of expertise is a massive plus as far as I am concerned. He spoke from a position of strength not merely as a theorist or theoretician but also as a practitioner. His credentials as an expert were in my view impressive, and he demonstrated that there was genuine substance behind them.

It is clear that Mr. Minor brought an open mind to the problem of the collapse, and that his investigations were done in an orderly, logical and methodical manner, in keeping with true engineering principles.

Professor Mitchell's role in the case was in a limited area. At first, the plaintiff's attorneys-at-law had indicated an eagerness for him to testify as it was thought that he supported the plaintiff's case. I cannot say that that thinking has been borne out. His evidence was simple; and he was not shaken in cross-examination. His credentials and his credibility have made Exhibit 40 a very valuable item in the case.

On the basis of my assessment of the witnesses, my understanding of the evidence they gave, and my understanding of the documentary evidence, I am satisfied that the silos did not collapse as a result of the factors advanced by the plaintiff. This is a case in which the plaintiff is blaming the collapse (which occurred on the 26th September, 1988), on the activities of the 12th September, 1988. Hurricane Gilbert was at the centre of activity on the 12th. According to the plaintiff, Gilbert "hit the bank of the silos.....inflicting its greatest damage at the bottom of the relevant bins, within the junction". "Gilbert initiated a chain reaction of imposition of internal stresses within the vertical junction between the bins", culminating "with the additional stresses by the filling of grain in bin 10 on September 26, 1988, when the bins failed and collapsed".

It was incumbent on the plaintiff to produce evidence to support this delayed action on the part of the hurricane as well as on the part of the silos. There really is no room for assumptions on such a matter.

The evidence produced by the plaintiff has fallen woefully short of that required in fact and in law. That which has been produced is flawed. The witnesses for the plaintiff have admitted to faulty calculations, incomplete computer runs so far as the supply of data is concerned, and in some areas the witnesses have professed lack of expertise in themselves. These deficiencies make it impossible for me to find on a balance of probabilities that the silos collapsed in the manner alleged in the statement of claim. There is a wide gap between the allegations and the acceptable evidence. Mr. Minor said that the results from Zetlin-Argo's computer runs are pure fantasy. It would seem that there is truth in that statement. Zetlin-Argo had a dream, apparently, but the witnesses were unable to transform that dream into reality.

Quite apart from the deficiencies that I have referred to, there is the situation which indicates that the plaintiff's investigators started off with a theory and worked towards the proof of that theory. There can be little wonder therefore that the evidence was so skewed. The Court's judgment cannot be based on unproven theory. There has to be a substratum of reliable facts. That is missing in this case that has been presented by the plaintiff.

The failure of the plaintiff to satisfy me that the silos collapsed as a result of the factors that it has alleged is, in my judgment, sufficient for judgment to be entered against the plaintiff and in favour of the defendants. However, in view of the full presentation by the defence, it is appropriate and important that I should state that I accept the expert opinion of Mr. Minor as to the cause of the collapse. In accepting the position advanced by the defence, I should stress that this was not merely a matter of accepting Mr. Minor as opposed to Mr. Cader. Whereas it is a fact that I have found Mr. Minor's knowledge of the subject matter under investigation to be sound, and his reasoning compelling, it must be pointed out that I was also guided by some of those articles that

were exhibited --- they having been written by persons far removed from the case.

The documentary evidence presented indicates that the first reinforced concrete grain elevator ever built was at the turn of this century. It collapsed twice-- firstly, shortly after it had been put into use and, secondly, three years later (1903). Since then, it has been known that silos do collapse from time to time. Exhibit 87 examines the reasons for such collapse. This exhibit is a paper written by O.F.Theimer, a consulting engineer of Munich, Germany. It was presented in October 1968 at the Materials Handling Conference of the American Society of Mechanical Engineers held at Boston, U.S.A. The paper was further published in the Journal of Engineering for Industry, May 1969.

Exhibit 87 lists the following as the main reasons for the failure of reinforced concrete grain silos:

1. Inadequate foundation;

2. Inexperienced planning and statical analysis; and

3. Incorrect reinforcement and faulty structural work.

The evidence of Dr.Oweis rules out number 1 above, whereas the evidence that I have found to be credible points to number 3 as listed.

The exhibit makes reference to several failures that had occurred up to then. Designers of silos in the late 1960s, if they were serious about their work, would have been aware of the failures, the causes of such failures, and, without doubt, would have been expected to make their designs with such factors in mind. There is no reason to think that the writer of the paper was the only engineer who should have known these matters.

The article, it should be noted, by virtue of its reference to the fact that several of the silos had been in use for several years before collapse, discredits the thinking of Zetlin-Argo that silos do not collapse suddenly after they had been in use for several years, unless the conditions set out in Exhibit 5 are present.

I cannot agree with learned Queen's Counsel, Mr. Mahfood, that the acid test in this case is the test of history as for over twenty-two years the silos had operated comfortably. The case does not rest on history. If the case rested on history, then no building would ever collapse as history would always be in its favour.....until it collapses. Of course, if the case rested on history, there would not have been any need for the very expensive services of Zetlin-Argo who purported to be investigators of the cause of the collapse.

In the American Concrete Institute (ACI) Journal of August 1969, there is an article by SARGIS SAFARIAN, a registered civil engineer in several states of the United States of America, and partner and chief structural engineer with a company in Denver, Colorado. That article which was admitted as Exhibit 9c states that there had been at that time "increasing concern among engineers over the many storage silo failures occurring all over the world. Investigations show that the majority of the silo distresses occurred because operational pressures of the stored material were much higher than the pressures on which the designs of the silos were based.". The article is critical of the designs of silos in the United States, and informs us that as a result of the studies and findings of engineers, several European countries had **already adopted silo design codes, or modified existing codes to insure the safety and economy of new silos under actual loading conditions.** It is not without significance that these silos were designed by a United States based company.

Mr. Safarian is considered by me as one with the necessary knowledge and expertise, as the said article refers to him as having worked in several European countries, and as being a specialist in silo structures who has been responsible for structural design of numerous industrial plants, terminals, storage silos and other structures. Further, in the ACI Journal of March, 1969 (Exhibit 9b), he is listed as a member of the American Concrete Institute. It is also noted that there has been no challenge to his credentials.

These two exhibits that I have referred to give considerable support to the opinions expressed by the witnesses for the defence, and thoroughly discredit the approach and position of the plaintiff. I see no reason to quote from other articles that were exhibited.

In view of the reasons that I have heretofore set out, I have no hesitation in entering judgment for the defendants. Indeed, as I see it, there is no alternative as the plaintiff has not proven that which it has alleged. Its witnesses have been discredited; their investigations have innumerable errors; and much of the investigations have been stage-managed to produce desirable results. The probabilities are overwhelmingly in favour of the position put forward by the defence.

The defendants are to have judgment with costs to be agreed or taxed.