A REVIEW OF SPECIFICATION REQUIREMENTS WITH RESPECT TO TIME ON THE CONCRETE BLOCKS USED FOR DALLAS/FORT WORTH INTERNATIONAL AIRPORT

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SUMMARY

Between August and October 1990, approximately one million concrete blocks were laid on three cross taxiways at Dallas/Fort Worth International Airport. The concrete blocks were not manufactured to the traditional ASTM requirements, but in line with the detailed specification written specifically for this project. It was necessary for the manufacturer to produce the blocks using a mix design and materials he had not previously used. In order to ensure compliance with the specification requirements for tensile splitting strength and compressive strength, a regular testing regime was set up on specimens from each days manufacture. This paper describes the test methods and presents the manufacturers test results together with the "compliance testing" results carried out by the Airport. The test results enable an overview of the variability and improvement with time of the block properties. The ratio of tensile to compressive strengths are also considered.

BACKGROUND

In 1990, Nigel Nixon and Partners designed and specified the pavement construction for three cross taxiways (Taxiways 23, 27 and 29) at Dallas/Fort Worth International Airport. The total area of these taxiways was approximately 23,500m^2. The taxiways were designed for a 20 year design life of trafficking by all aircraft types, from small private aircraft to passenger and cargo DC-10s and 747s. This required designing for individual wheel loads in excess of 25 tonnes.

The specification for the concrete blocks was produced so that the blocks would perform satisfactorily on a pavement with the most onerous of performance criteria. As such the specification required enhanced properties over and above the requirements of ASTM C936 "Standard Specification for Solid Interlocking Concrete Paving Units". The manufacturer found it necessary to alter his standard mix design and aggregates to provide a conforming product. The primary change was to the type of material used for the fine aggregate. Traditionally the materials available in the Dallas area, for both coarse and fine aggregates, were of limestone origin. A harder, more durable material was required to comply with the specification, and it was necessary to import the fine aggregate from a granite source. Changes were also made to the mix proportions and additives to ensure that the blocks complied with the other requirements.

The installation of the concrete blocks was carried out from the end of August through October 1990, although the appointment of the manufacturer, Pavestone Company, was not made until mid August.

The first blocks were delivered to site for laying fourteen days after manufacture. The Airports compliance testing was not carried out until the blocks were 28 days old, therefore the entire responsibility for these blocks achieving the specified properties lay with the installer and manufacturer. In order to be confident as to the performance of the blocks, a regular series of tests were carried out on the blocks at various ages. These tests were in accordance with the tensile splitting test and the compressive test specified, and were carried out at various dates including 7, 14, 21, 28 and 56 days after manufacture. This testing was sufficient for the manufacturer to confidentially supply the blocks prior to acceptance testing. It also enabled vibration of the surface to be delayed until the blocks had achieved a suitable strength so as to prevent undue damage.

After three weeks of installation, all blocks delivered to the site were in excess of 28 days old and had passed the airports acceptance testing. The manufacturer continued his testing program to provide a complete set of data on the blocks.

SPECIFICATION FOR THE CONCRETE BLOCKS

Nigel Nixon and Partners Specification for the blocks was generally in line with ASTM C936, but certain additional tests were required and some of the properties were enhanced. The completed pavement surface had to be suitable to resist degradation from materials such as de-icing and anti-icing chemicals, fuel and hydraulic oils. An acceptable skid resistance was required to be maintained. The surface was also required to be stable and resist the effects of high temperatures and repeated freeze/thaw cycles.

The blocks were required to be manufactured from hydraulic cement concrete containing normal weight aggregates. The cement was to be either Portland cement complying with the requirements of ASTM C150 or blended hydraulic cement conforming to the requirements of ASTM C595. The aggregates were to comply with the requirements of ASTM C33 with the exception of the grading requirements, and were to consist of naturally occurring crushed or uncrushed materials. The fine aggregate was to contain a minimum of 50% of siliceous type sand. The blocks were to be rectangular with a nominal size of 100 x 200 x 80mm with a dimensional tolerance of 1.5mm on length and width and 3mm on thickness. In addition the cumulative dimensions of twenty blocks had to be within established limits.

Twenty blocks were selected for testing from a lot of 100,000 blocks or one days manufacture, whichever was less. All the blocks were checked for density and dimensional variation. Three blocks were subjected to a de-icing freeze/thaw durability test in accordance with the Canadian Specification CAN3-A231.2-M85. Four blocks were tested for absorbtion in accordance with ASTM C140 and three blocks were tested for abrasion resistance in accordance with ASTM C418.

Of the remaining blocks in the sample five blocks were tested for compressive strength in accordance with ASTM C140 and five blocks were tested for tensile splitting strength in accordance with ISO 4108. The compressive strength requirements was such that the average value of the test samples at 28 days was not to be less than $55N/mm^2$ and no individual block was to fail at less than $50N/mm^2$. The tensile splitting strength requirement was such that the minimum value of the test samples at 28 days was not to be less than $4.5N/mm^2$.

COMPRESSIVE TESTING

The compressive testing was carried out in accordance with ASTM C140 "Standard Methods of Testing Concrete Masonry Units". The testing machine is equipped with two steel bearing plattens to transmit the load evenly to the concrete block. The blocks are stored at normal room temperature and are capped, top and bottom, with a thin layer of proprietary material to ensure even loading of the sample. The specimens are placed in the testing machine with their central axis directly under the centre of thrust. The load is applied up to half of the expected failure load at a convenient rate but is then adjusted so that the remaining half of the load is applied uniformly for a period of between one and two minutes until failure.

The compressive strength of the block is calculated from the maximum load and cross section area of the block. The compressive strength (fc) is given by the formula:

$$f_c = \frac{F}{(l \times b)} \quad N/mm^2$$

Where F = load at failure (N)
l = length of concrete block (mm)
b = width of concrete block (mm)

TENSILE SPLITTING TEST

The testing was carried out in accordance with ISO 4108 "Concrete - Determination of Tensile Splitting Strength of Test Specimens". The testing machine is equipped with two steel loading pieces between the plattens of the machine. These are longer than the specimen is wide, and have a cross sectional shape of the segment of a circle with a radius of 75mm to ensure a true line load. The test specimen is placed centrally in the testing machine with its axis horizontally between the loading pieces which are directly over one another. Ine specimen is isolated from the steel loading pieces by thin timber packing strips to ensure even loading.

The load is applied continuously and at a uniform rate of $0.06 \pm 0.04N/mm^2$ per second and the testing time should be at least 30 seconds. Upon failure of the specimen, the maximum load is noted from the machine, and the tensile splitting strength, ft is given by the formula:

$$f_t = \frac{F}{(\pi \times b \times d)} \quad N/mm^2$$

Where F = load at failure (N)
b = length of line of contact (mm)
d = depth of test specimen (mm)

RESULTS

The results of both the Airports and the manufacturers compressive testing are presented in Table 1. The Airport values are the average of five test results for any one days manufacture, together with the minimum value from the five tests. The manufacturers values are the average results from samples of three blocks. The acceptance testing shows that all materials complied with the specification whilst the manufacturers testing shows an increase in strength with the age of the blocks.

The results of both the airports and the manufactures tensile splitting testing are presented in Table 2. The values represent the same sample sizes considered for Table 1. The acceptance testing shows that all materials complied with the specification whilst the manufacturers testing shows an increase of strength with time.

Table 3 presents the ratio of tensile strengths to compressive strengths for both the average acceptance testing values and the manufacturers values. Figure 1 depicts the general increase in compressive strength with time, whilst figure 2 depicts the general increase in tensile splitting strength with time. Figure 3 indicates the range of tension to compression ratios at the various test dates.

CONCLUSIONS

The results show that the concrete blocks complied with the Specification both for compressive strength and for tensile splitting strength.

The plot of compressive strengths depicted in Figure 1 shows a rapid gain in strength during the early life of the blocks such that the target strength was achieved at fourteen days. From this stage the strength gain was both uniform and gradual up to fifty six days.

The plot of tensile strengths depicted in Figure 2 shows a rapid gain in strength over the first seven days, but that it was twenty eight days before the target strength was achieved. From seven days the gain in strength was both uniform and gradual up to fifty six days.

The ratio of tensile splitting strength to compressive strength averaged 8.3% at 28 days. There is a slight linear increase in this figure with the age of the specimens. This indicates that the tensile requirement was the most onerous strength clause in the Specification (9%).

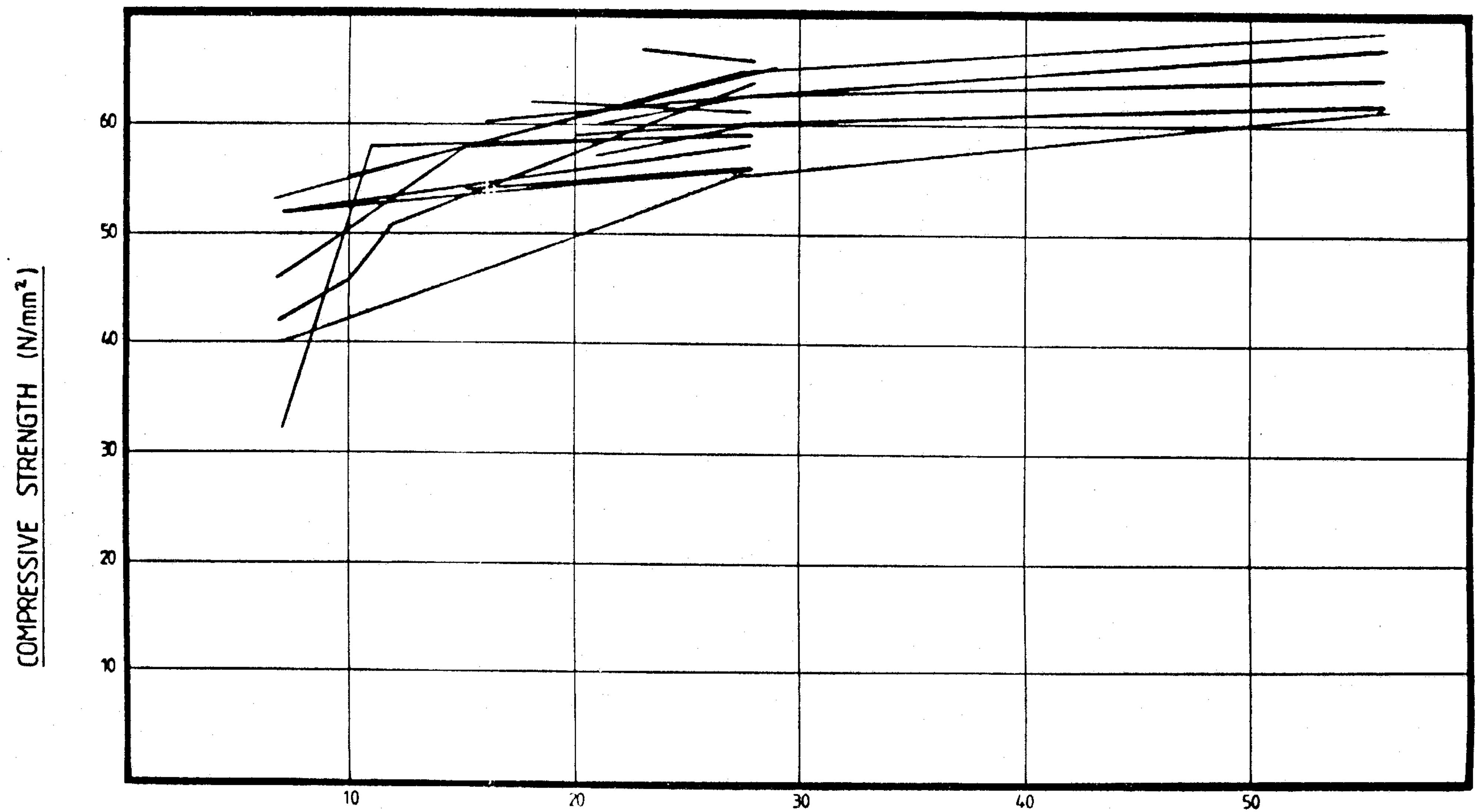
The figures presented indicate that early compressive or tensile splitting testing of concrete blocks could enable a manufacturer to evaluate various mix designs and be confident that his blocks will meet specification requirement at twenty eight days.

COMPRESSIVE TESTING

MANUFACTURE DATE	ACCEPTANCE TESTING		MANUFACTURERS TESTING			
	f_c average (N/mm^2)	f_c minimum (N/mm^2)	AGE/STRENGTH days/(N/mm^2)			
08-21-90	62	56	10/55	14/Na	22/Na	29/65
08-24-90	60	54	7/52	19/Na	28/56	
08-27-90	58	54	8/52	16/Na	28/58	
09-07-90	56	53	7/42	10/46	12/51	28/64
09-10-90	60	56	7/32	11/58	28/59	
09-11-90	59	56	7/46	15/58	28/59	
09-12-90	58	56	15/54	28/56		
09-13-90	61	57	18/62	28/61		
09-14-90	59	56	20/59	28/60		
09-15-90	60	57	20/60	23/Na	28/62	
09-17-90	62	60	23/67	28/66		
09-26-90	58	55	16/60	28/63	56/67	
09-27-90	64	59	21/60	28/63	56/64	
09-28-90	58	56	21/57	28/60	56/62	
09-29-90			24/62	28/63	56/67	

TABLE 1

COMPRESSIVE STRENGTH GAIN

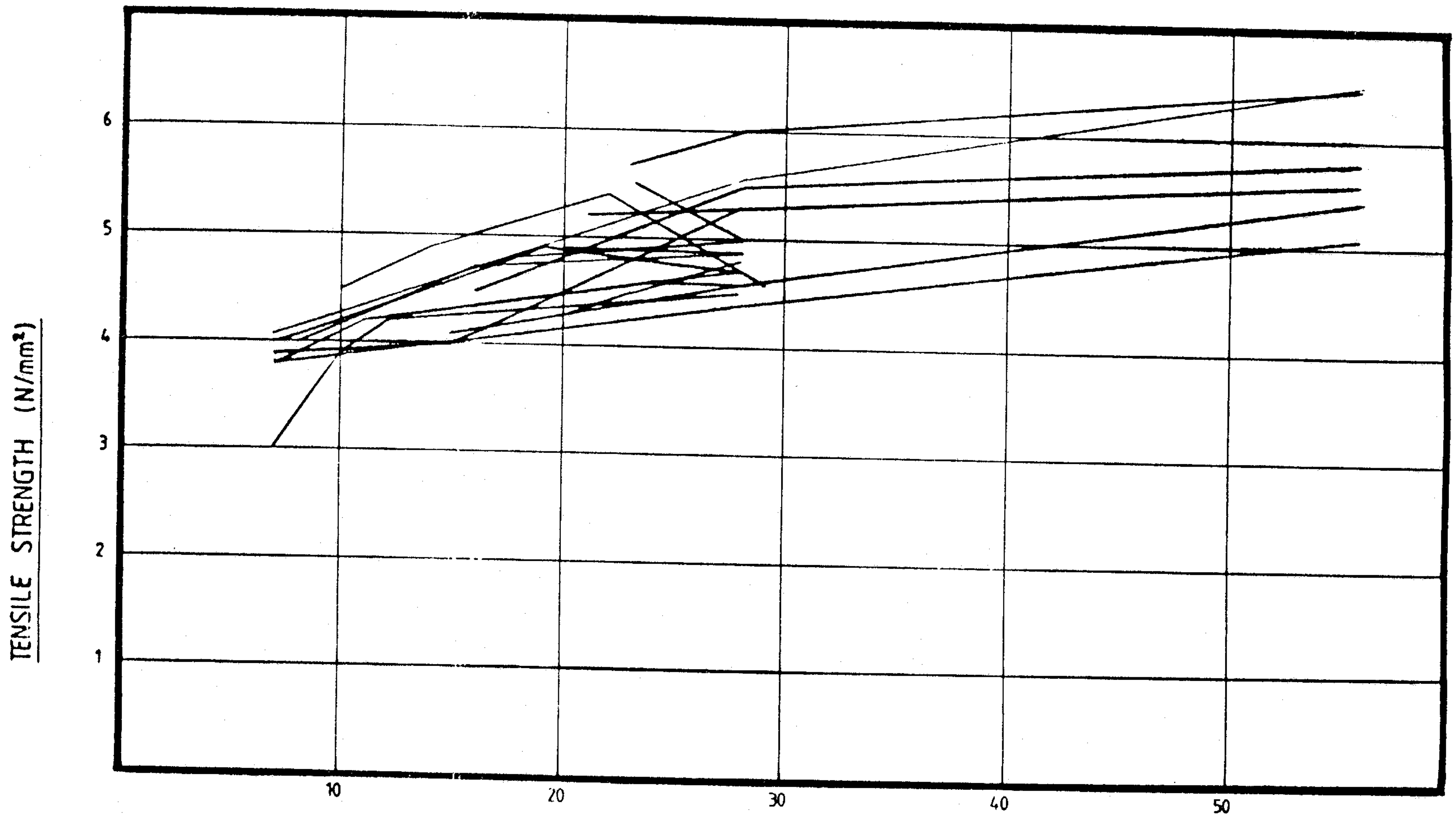


TENSILE TESTING

MANUFACTURE DATE	ACCEPTANCE TESTING		MANUFACTURERS TESTING			
	f_t average (N/mm^2)	f_t minimun (N/mm^2)	AGE/STRENGTH days/(N/mm^2)			
08-21-90	5.9	5.6	10/4.5	14/4.9	22/5.4	29/4.6
08-24-90	4.8	4.7	7/4.0	19/4.9	28/4.7	
08-27-90	5.0	4.5	8/4.0	16/4.7	28/4.9	
09-07-90	5.0	4.7	7/3.0	10/3.9	12/4.2	28/4.5
09-10-90	4.8	4.5	7/3.8	11/4.2	28/4.7	
09-11-90	4.7	4.6	7/3.9	15/4.0	28/5.3	
09-12-90	4.8	4.7	15/4.1	28/4.6		
09-13-90	5.3	5.1	18/4.8	28/5.0		
09-14-90	5.1	4.9	20/4.9	28/4.9		
09-15-90	4.9	4.7	20/4.3	23/4.5	28/4.8	
09-17-90	4.9	4.6	23/5.5	28/5.0		
09-26-90	4.7	4.5	16/4.5	28/5.5	56/5.8	
09-27-90	5.1	4.9	21/5.7	28/6.0	56/6.5	
09-28-90	5.0	4.8	21/5.2	28/5.3	56/5.6	
09-29-90			24/4.6	28/4.6	56/5.4	

TABLE 2

TENSILE STRENGTH GAIN



COMPRESSION TENSION RATIO

MANUFACTURE DATE	ACCEPTANCE TESTING	MANUFACTURERS TESTING			
	average	AGE/RATIO			
08-21-90	9.5	10/8.1	14/Na	22/Na	29/7.0
08-24-90	8.0	7/7.5	19/Na	28/8.5	
08-27-90	8.6	8/7.7	16/Na	28/8.6	
09-07-90	3.9	7/7.3	10/8.6	12/8.3	28/7.1
09-10-90	5.0	7/11.6	11/7.2	28/7.9	
09-11-90	8.0	7/8.5	15/6.9	28/9.0	
09-12-90	8.3	15/7.6	28/8.2		
09-13-90	8.7	18/7.7	28/8.2		
09-14-90	8.6	20/8.3	28/8.1		
09-15-90	8.2	20/7.2	23/Na	28/7.7	
09-17-90	7.9	23/8.2	28/7.6		
09-26-90	8.1	16/7.5	28/8.7	56/8.7	
09-27-90	8.0	21/9.5	28/9.6	56/10.1	
09-28-90	8.6	21/9.0	28/9.0	56/9.2	
09-29-90		24/7.4	28/7.4	56/7.9	

TABLE 3

TENSILE/COMPRESSIVE STRENGTH RATIO

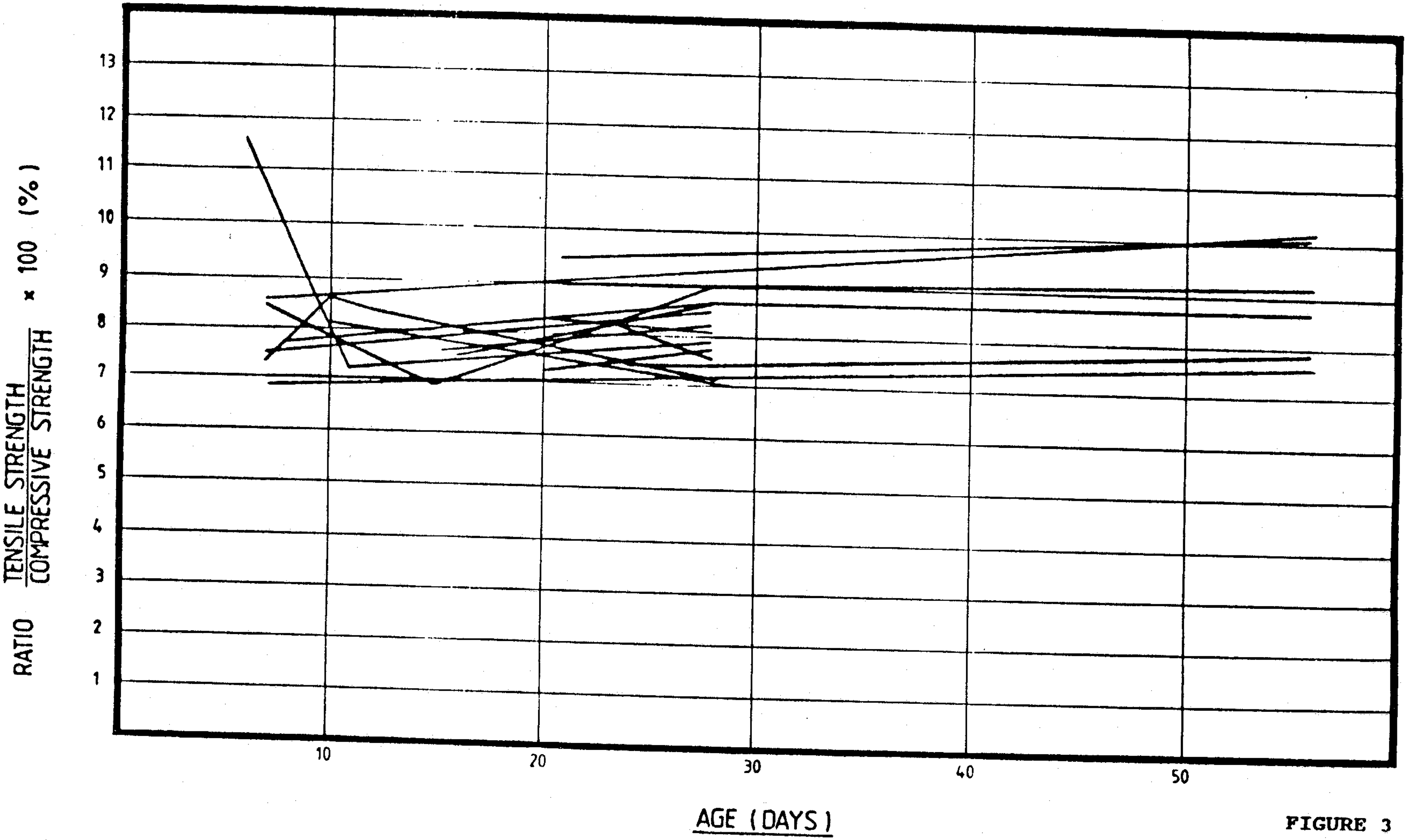


FIGURE 3