ON FACTORY QUALITY CONTROL POSSIBILITIES FOR CONCRETE BLOCKS (A SIMPLE QUALITY'S TEST PROPOSED AT THE END OF AN EXPERIMENTAL RESEARCH ON PAVING ELEM

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Summary

An experimental research conducted by the authors in '87 with the cooperation of various Pavi firms is shortly described.
Non-destructive and destructive methods were used with the aim to reach simple methods of that can be adopted for a simple but reliable quality control in the factories producing c blocks paving elements.
A non-destructive verification of elastic moduls with so-called sonic methods, coupled wit structive simple bending test and an water immersion test (starting from a well known situati proposed as possible solution.

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General

During 1987 the authors an account of Pavitalia and with the support of three companies associated to Pavitalia (Record, LecaBeton, P.C.) conducted an experimental research to verify the possibilities of a simple quality control of paving elements with methods that can be used also in the conditions of production centers.
In various time pieces with hidden defects and pieces with slightly different characteristics or with very unusual shapes were produced and controlled by the research team with the cooperation of eng. Beretta of Pavitalia.
These elements were tested in many different ways, with destructive and non-desctructive methods, to verify if it were possible to find a simple method(s) that, possibly integrated with a few random official laboratory's verifications, can give to the responsable of quality control of the company producing the elements, the real possibility to at least compare immediately the characteristics of the products he is producing with what was tested and deeply verified one year (six months) before in a well-equipped official laboratory (basically we were trying to find a comparison method) and to detect immediatly possible defects hidden into the pieces.

Main tests conducted

Many tests were conducted with the support of ICITE laboratories (Istituto Centrale di Tecnologia Edilizia of C.N.R.) in a conditionated zone (50 % U.R. - 20 °C). The first aim was to verify the possibilities of to detect defects (small layers of papers intr into pieces during production) of p then to verify the "qualities" of prc For this were produced pieces with regular shape and with small differe As a general approach the various test conducted first with well equipped lab ry's instruments, then with the simple a tus that was possible to propose for c on production's sites.
Laboratory's controls samples ~4x4x were cutted from the blocks and teste the usual compression methods.
For on site control a recording Schmi hammer (the-low energy type (0,75 Kg.m found to be preferably to the usual energy type) (fig. 1) was used. The r were rather good for the control of comp ve resistence of concrete but not satisf to surely detect the defects (simulatir lamination of the various layers of th crete of the paving blocks etc.).
Seen the results a sonic methods wa The methods resulted quite satisfacto the verifications of production defect when a simple (see fig. 2) field testing ratus was used.
The results of the test on two types c ments are given as a sample of the ac that can be reached (see table I and II Then on the same samples (the previou was non desctructive!) a water immersi was carried on (see table III).
It was possible to verify (and the was confirmed by all the following see table IV) that is more significa sure to refer to variation of weight water immersion more than to a dryir

since that, also using a stove the time of drying is rather long (4 days!) mean while in less than two days (really 4-6 hours) the wet weight reached for immersion is stable and so, if it is possible to operate with samples simply stocked in covered zones, it is easy to reach significant results.

Then we tried to rely the lab. results reached on samples cutted out (and this is obviuosly possible only in lab. conditions!) from blocks with the results reached with compression on the entire blocks (prepared - smoothed - and not prepared) (table VI) and a comparison among "Sonic", the so called "Splitting test", and a bending test (as proposed by the authors see fig. 4).

The b. tests were repeated for different span and on the fragmets produced by the previous ruptures. As it can be easily seen in fig. 5 and in tables VIII, the value of the rupture's moment that can be calculated are almost indipendent by the ratio thickness/span (s/b) (up to value of span of the same order of the thickness) and the modes of the fracture are very uniform (see fig. 5).

So the authors insisted in this type of test with many different shapes of elements and the results confirmed that this approach is very simple and significant.

Obviuosly the water immersion and drying test were carried on the same elements (before mechanicale tests) and they too confirmed what was found before.

Conclusions

The target of the research was to find and to check a simple method that, on the factory's real situation, was proposable for quality control.

The tests were conducted (Hammer tests, Sonic drying and water immersion, compression on cubes cutted out from the paving blocks etc..) on the production of three companies on 8-10 different shapes of products, on more than 400 samples. It was found that:

1) Hammer test (also with low-energy sclerometer) may be significant only to check the E value of the concrete and not the quality of the blocks (it was impossible to check out the defects introduced into the pieces).
2) Drying and water immersion methods are significants but only the w.i. can be proposed in factory (due to the long times and the equipments necessary for drying tests).
3) "Sonic" methods is excellent to verify the overall quality of concrete and to control the absence of cracks, layers etc
4) Bending tests of the type proposed gi a real traction value of the resister of the paving block and is extremely reli ble and simple to be done (much more th a conventional Splitting test which probably suffering of the variation the friction coefficient between the pla of testing machine and the concrete.

So, taking into account that is obvious necessary refer to a fundamental "checki done on the production by a well equip external laboratory (that will use all classical methods of testing), the auth suggest the possibility to adopt a proced of comparison based on the values found w a water-immersion test + sonic (possibly in grated with hammer test) + "bending" t as described with s/b value of 1-1,5.

These controls can be carried on with pratica all the types of paving-blocks under p duction by the companies associated to Pa talia.

The equipment necessary for this routine simple and not expansive and the man in cha of the control does'nt need an important tra ning (he can reach an acceptable level qualification after a training of 2-3 days)

TAB. I.

- "RED" PAVING BLOCKS -

n°	t_1 (μs)	t_2 (μs)	t av. (μs)	$\Delta = t_1 - t_2$
1	15,8	15,5	15,65	0,30
2	15,8	15,3	15,55	0,30
3	15,3	15,6	15,45	0,30
4	15,2	15,5	15,35	0,30
5	15,3	15,4	15,35	0,10
6	15,8	15,5	15,65	0,30
7	15,6	15,8	15,70	0,20
8	15,6	15,4	15,50	0,20
9	15,9	15,4	15,65	0,50
10	15,7	15,7	15,70	0,00
11	16,6	15,6	16,10	1,00
12	15,8	15,5	15,65	0,30
13	15,2	15,4	15,30	0,20
14	15,0	15,2	15,10	0,20
15	15,4	15,4	15,40	0,00
16	15,2	15,3	15,25	0,10
17	15,5	15,3	15,45	0,20
18	15,4	15,3	15,35	0,10
19	15,0	15,3	15,15	0,30
20	15,8	15,7	15,75	0,30

Att.! - 1 = first measure
- 2 = second measure

TAB. II

- "GREY" PAVING BLOCKS -

n°	t_1 (Kg/cm²)	Δt_1 (%)	t_2 (Kg/cm²)	Δt_2	$\frac{\Delta t_2}{\Delta t_1}$	WEIGHT (Kg)	t_1 av. (Kg/cm²)	t_2 av. (Kg/cm²)
1	28,3 28,2	0,35	15,3 15,1	1,31	9,743	3,440	28,25	15,15
2	29,2 29,0	0,68	16,0 16,0	0,00	0,000	3,375	29,10	16,00
3	29,5 29,0	1,69	15,6 15,8	1,28	0,757	3,440	29,25	15,70
4	29,0 28,2	2,76	15,6 15,9	1,92	0,696	3,420	28,60	15,75
5	29,2 28,6	3,22	14,7 15,0	1,04	0,323	3,375	28,90	14,85
6	28,7 30,8	7,32	15,5 16,0	3,23	0,441	3,400	29,75	15,75
7	28,5 29,3	2,81	15,8 16,5	4,43	1,577	3,410	28,90	16,85
8	29,0 29,6	2,07	15,3 15,5	1,31	0,633	3,425	29,30	15,40
9	30,6 31,2	1,96	17,8 17,6	1,12	0,571	3,405	34,90	17,70
10	29,2 29,5	1,03	15,8 16,3	3,16	3,068	3,380	29,35	16,05
11	30,4 28,0	7,89	15,9 16,2	1,89	0,240	3,340	29,20	16,05
12	28,6 29,3	2,45	15,5 15,8	1,94	0,792	3,385	28,95	15,65
13	29,6 28,7	3,04	15,8 15,6	1,27	0,418	3,350	29,15	15,70
14	30,1 27,8	7,64	15,9 16,0	0,63	0,082	3,350	28,95	15,95
15	29,0 28,9	0,34	15,2 15,6	2,63	7,735	3,410	28,95	15,40
16	27,9 29,5	5,73	15,2 15,6	2,63	0,459	3,380	28,70	15,40
17	29,5 31,0	5,08	15,7 15,8	0,64	0,125	3,340	30,25	15,75
18	30,6 29,2	4,58	16,0 16,3	1,88	0,410	3,360	29,90	16,15
19	31,2 28,7	8,01	16,7 16,6	0,60	0,075	3,420	29,95	16,65
20	31,2 30,6	1,91	16,5 17,2	4,24	2,220	3,350	30,90	16,85
$\bar{x}$		6,63		1,86		3,390	29,36	15,94
s		2,58		1,21		0,030	0,71	0,66
cv		73,11%		54,79%		0,970	2,42%	4,15%

Att.! - 1 is the lenght of block - 2 is the thickness

TAB. III

TIPO	CAMP.	external (gr)	dry heated 1 g.	dry heated 4 gg.	dry heated 6 gg.	dry heated 7 gg.	dry heated 8 gg.	dry heated 22 gg.
grey	1	3.400	3.367	3.311	3.468	3.468	3.469	3.479
	2	3.415	3.380	3.327	3.496	3.498	3.498	3.509
red	1	3.520	3.479	3.410	3.578	3.580	3.581	3.588
	2	3.535	3.498	3.441	3.608	3.610	3.612	3.620
	3	3.555	3.510	3.450	3.622	3.622	3.625	3.635
	4	3.650	3.600	3.528	3.700	3.700	3.702	3.710

TAB. IV

		N	BLUE	N	BROWN	N	GREEN
Stove		1	3.907	3	3.810	5	3.798
		2	3.925	4	3.810	6	3.838
1 g. stove		1	3.785	3	3.707	5	3.710
		2	3.813	4	3.708	6	3.740
h. 9.10	15.07.87	1	3.779	3	3.701	5	3.705
2 gg. stove		2	3.804	4	3.706	6	3.738
ore 17	15.07.87	1	3.779	3	3.700	5	3.703
		2	3.803	4	3.703	6	3.738
6 gg. water immersed		1	4.000	3	3.928	5	3.935
		2	4.025	4	3.928	6	3.962
	30.07.87	1	4.008	3	3.941	5	3.945
		2	4.029	4	3.940	6	3.974
	07.08.87	1	4.013	3	3.945	5	3.952
		2	4.037	4	3.945	6	3.980
	14.09.87	1	4.019	3	3.961	5	3.955
		2	4.045	4	3.958	6	3.990
1 g. air	15.09.87	1	4.000	3	3.922	5	3.929
		2	4.029	4	3.926	6	3.955
h. 16	15.09.87	1	3.995	3	3.917	5	3.925
		2	4.025	4	3.921	6	3.955
2 gg. air	16.09.87	1	3.984	3	3.905	5	3.915
		2	4.018	4	3.910	6	3.945
	17.09.87	1	3.975	3	3.891	5	3.903
		2	4.007	4	3.898	6	3.930
	21.09.87	1	3.950	3	3.863	5	3.871
		2	3.980	4	3.870	6	3.930
	28.09.87	1	3.932	3	3.842	5	3.847
		2	3.960	4	3.848	6	3.880
	01.10.87	1	3.927	3	3.837	5	3.838
		2	3.955	4	3.843	6	3.874
	05.10.87	1	3.922	3	3.833	5	3.834
		2	3.949	4	3.838	6	3.872
	08.10.87	1	3.916	3	3.828	5	3.829
		2	3.942	4	3.833	6	3.867
	22.10.87	1	3.913	3	3.825	5	3.823
		2	3.940	4	3.829	6	3.863
	02.11.87	1	3.907	3	3.815	5	3.815
		2	3.933	4	3.818	6	3.852

TAB. V

	n°	SIZE h	SIZE base	WEIGHT (gr)	FAILURE (Kg)	
BROWN	1	5,73	5,76 - 5,73	439	15.750	
	2	5,74	5,76 - 5,67	413	12.900	
	3	5,74	5,70 - 5,74	428	17.100	
	4	5,73	5,75 - 5,68	416	14.600	
	5	5,73	5,75 - 5,65	428	18.750	
	6	5,73	5,66 - 5,70	418	16.900	
	7	5,73	5,73 - 5,67	418	16.000	
	8	5,73	5,73 - 5,73	436	20.000	
	9	5,72	5,73 - 5,76	426	16.200	
	AV.					504 Kg/cm² s = 64.5 cv% = 12.8
GREEN	1	5,71	5,77 - 5,79	438	19.500	
	2	5,69	5,74 - 5,79	434	18.750	
	3	5,70	5,77 - 5,79	432	17.700	
	4	5,70	5,76 - 5,74	421	14.700	
	5	5,70	5,77 - 5,74	418	13.300	
	6	5,69	5,77 - 5,74	438	21.500	
	7	5,71	5,74 - 5,77	430	16.300	
	8	5,69	5,74 - 5,74	425	15.900	
	9	5,69	5,75 - 5,77	437	19.800	
	AV.					527 Kg/cm² s = 79 cv% = 15
BLUE	1	5,65	5,70 - 5,74	427	18.600	
	2	5,69	5,70 - 5,74	425	16.600	
	3	5,68	5,77 - 5,74	429	19.300	
	4	5,68	5,72 - 5,75	425	17.300	
	5	5,70	5,73 - 5,75	428	17.800	
	6	5,70	5,72 - 5,76	430	19.400	
	7	5,69	5,70 - 5,73	428	21.200	
	8	5,69	5,68 - 5,78	433	21.750	
	9	5,69	5,79 - 5,72	432	18.050	
	AV.					570 Kg/cm²

Att.: - Charge in the cast compaction direction

TAB. VI

GREY
COMPRESSION

	n°	(cm)	(Kg)		t_1 av. μsec	t_2 av. μsec
PREPARED	1	5,9	211.100		28,25	15,15
	2	6,0	191.000	$\bar{x}$ = 206.140	29,10	16,00
	4	5,7	231.000	s = 15.892	28,60	15,75
	5	5,9	195.000	cv = 7,71%	28,90	14,85
	10	6,0	202.500		29,35	16,05
NOT PREPARED	6	6,1	160.800		29,75	15,75
	9	6,3	134.600	$\bar{x}$ = 148.840	30,90	17,70
	8	6,1	144.000	s = 9.968	29,30	15,40
	12	6,1	153.600	cv = 6,70%	28,95	15,65
	19	6,1	151.200		29,95	16,65

SPLITTING TEST

PREPARED	13	6,9	4.800		29,15	15,70
	14	6,0	4.400	$\bar{x}$ = 4.340	28,95	15,95
	15	5,9	3.600	s = 477	28,95	15,40
	18	5,9	4.700	cv = 11,00%	29,90	16,15
	20	5,9	4.200		30,90	16,85
NOT PREPARED	3	6,1	5.500		29,25	15,70
	7	6,15	5.800	$\bar{x}$ = 4.900	28,90	16,85
	11	6,1	3.700	s = 834	29,20	16,05
	16	6,05	5.000?	cv = 17,01%	28,70	15,40
	17	6,1	4.500		30,25	15,75

TAB. VI'

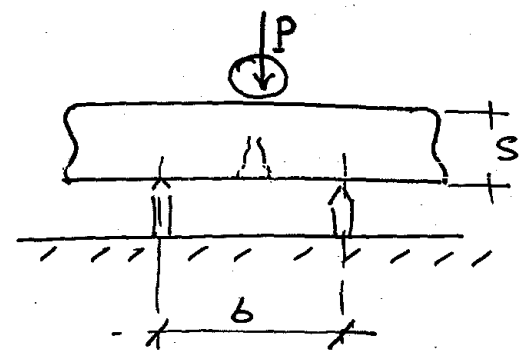
	COMPRESSED				SPLITTING TEST			
		(cm)	(Kg)			(cm)	(Kg)
PREPARED	1	5,9	211.200	PREPARED	13	5,9	4.800
	2	6,0	191.000		14	6,0	4.400
	4	5,7	231.000		15	5,9	3.600
	5	5,9	195.000		18	5,9	4.700
	10	6,0	202.500		20	5,9	4.200
NOT PREPARED	6	6,1	160.800	NOT PREPARED	3	6,1	5.500
	9	6,3	134.600		7	6,25	3.800
	8	6,1	144.000		11	6,1	3.700
	12	6,1	153.600		16	6,05	5.000 (?)
	19	6,1	151.200		17	6,1	4.500

TAB. VII

n°	SONIC (μsec) (*) BLUE	GREEN	BROWN	BENDING (Kg) (**) BLUE	GREEN	BROWN	SPLITTING TEST (Kg) BLUE	GREEN	BROWN
1	33,7	35,6	37,4	1.400	1.320	1.100	5.050	3.110	2.830
2	35,9	36,6	37,3	1.340	1.310	1.220	2.400	4.700	4.260
3	34,3	36,9	36,8	1.200	1.480	1.340	4.230	2.700	3.510
4	35,9	37,1	36,0	-	1.360	1.420	5.280	5.060	4.730
5	34,9	36,9	37,3	1.300	1.260	1.500	3.410	3.730	3.580
6	36,0	36,2	37,0	1.510	1.470	1.150	5.630	4.160	3.500
7	36,2	36,7	37,2	1.350	1.410	1.210	2.650	5.180	3.880
8	34,0	37,1	36,3	1.300	1.250	1.130	2.820	3.950	4.620
9	36,1	37,9	36,7	1.260	1.200	1.070	3.820	3.950	3.790
10	34,8	37,5	36,2	1.250	1.150	1.390	4.450	3.730	4.000

(*) Value read after 30 sec.

(**) In the center



TAB. VIII

BENDING TEST

GREEN	120 mm	91 mm	60 mm intero	60 mm f.right	60 mm f. left
	1.910	2.710	4.400	4.260	4.200
	1.680 (?)	2.605	4.550	4.600	4.300
	2.050	2.390	4.400	4.850	4.500
	1.960	2.950	3.980	3.900	4.100
	2.040	2.705	4.360	4.480	4.480
A.V.	1.930	2.670	4.338	4.418	4.316
BLUE	1.720	2.390	4.380	4.150	4.100
	2.010	2.630	3.940	3.880	4.100
	1.980	2.350	4.120	3.720	4.040
	1.970	2.350	4.100	3.900	4.180
	1.840	2.780	4.200	4.050	4.100
A.V.	1.900	2.500	4.150	3.940	4.104
BROWN	1.805	2.600	4.250	3.920	4.460
	1.805	2.820	4.250	3.880	4.200
	2.040	2.700	3.700	3.800	3.650
	1.820	2.500	4.120	3.860	3.960
	1.880	2.420	4.260	3.840	3.780
A.V.	1.870	2.608	4.116	3.860	4.010

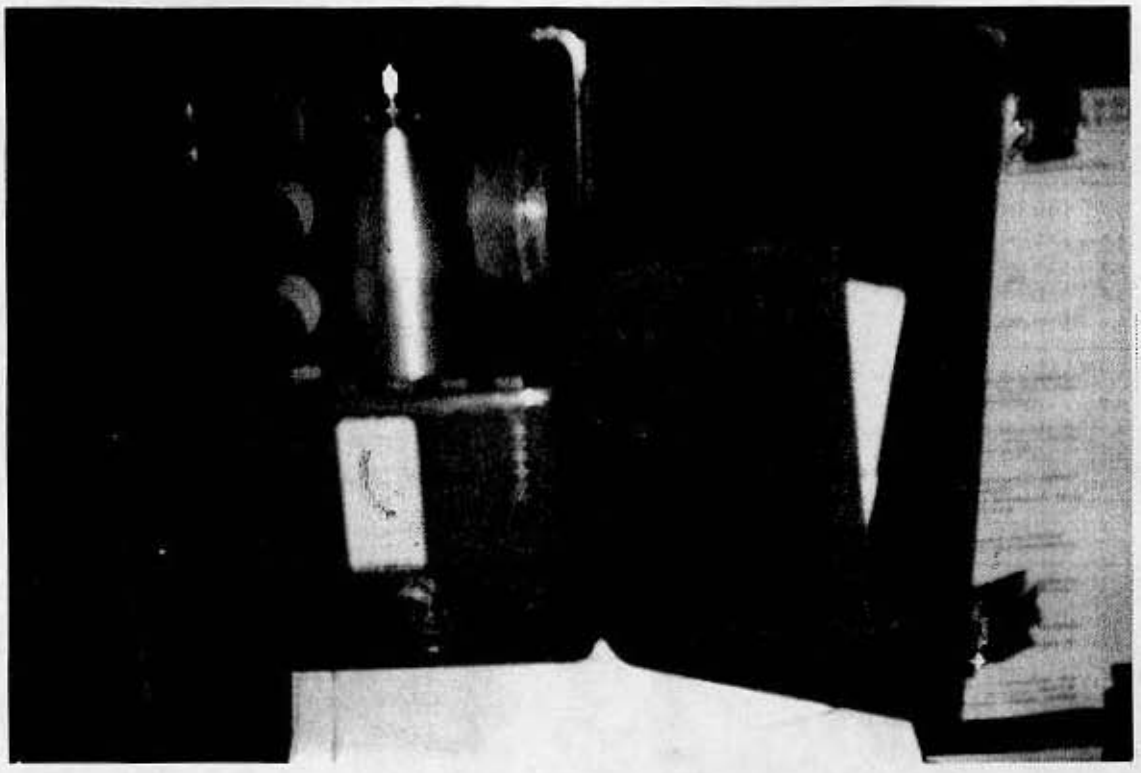


Fig. 1 - Hammer test



2 - "Sonic test"



Fig. 3 - (verification of production defects

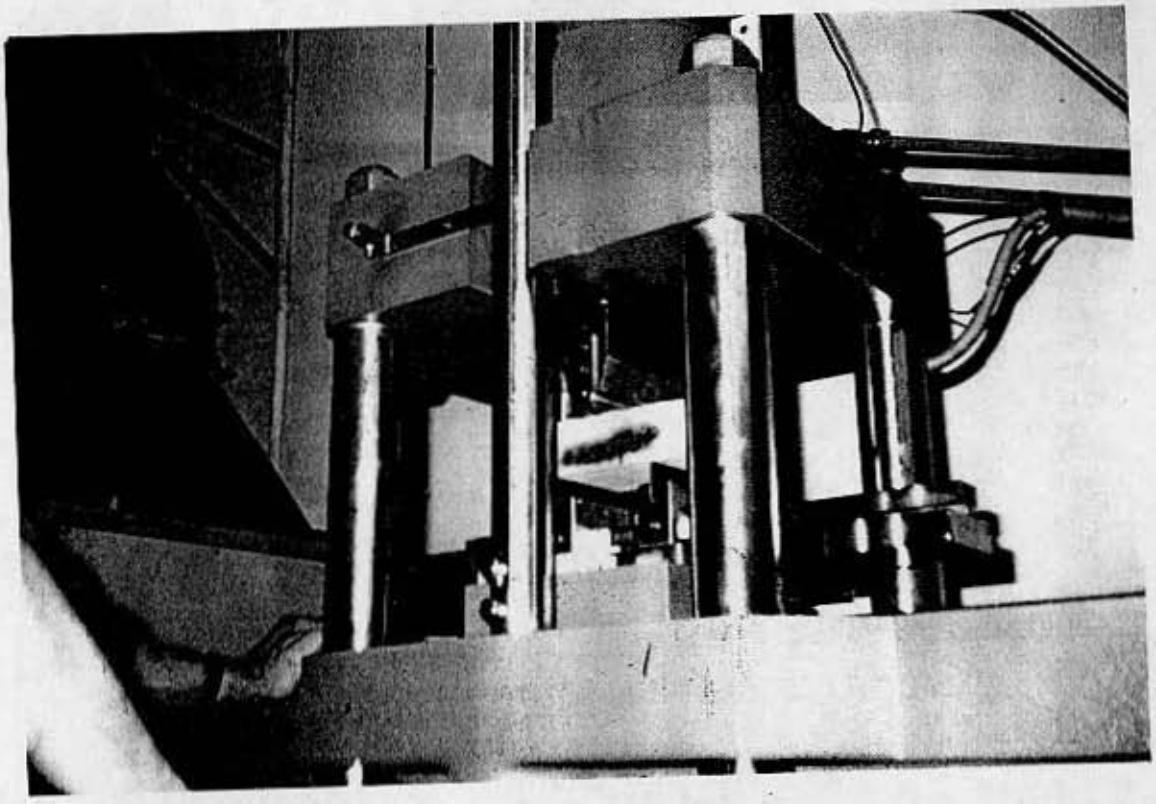


Fig. 4 - "Bending"



Fig. 5 - "Modes of fracture"