Chapter 13

Water Absorption in Cbp

13.1 Introduction

13.1.1 Literature Survey

Water absorption is primarily a function of the pore and capillary structure of hardened cement paste, and is particularly influenced by the density, the diameters, and the continuity of the capillaries.

Powers(1958) gives a useful introduction into this subject:

‘Any solid composed of particles randomly aggregated is both porous and permeable. Since cement paste has such a structure, it is intrinsically porous and permeable. The densest possible completely hydrated cement paste has a porosity of approximately 26%. The porosity depends on the original water content and on the extent to which space has become filled with hydration products. It depends therefore on the original water/cement ratio and on the conditions of curing.

The permeability of paste as a whole depends mostly on its capillary porosity, for the resistance to flow through the capillary cavities is much smaller than through the gel. (Gel is made up of solid needle like CSH structures separated by very small gel pores. The gel pores are a few orders of magnitude smaller than the capillary pores).

Dry paste absorbs a lot of water, leading early researchers in the physical properties of hardened Portland cement paste to conclude that it consisted of a network of capillaries. In about 1939 the concept changed and pores were thought of as spaces among the particles (interstitial spaces).

The main component of cement paste is cement gel, which develops in the water filled spaces within the visible boundaries of a body of paste. Space filled with gel contains gel pores, space not filled with gel or other solid material is capillary space.’

Sukandar(1993) stated that the total volume of pore space is measured by absorption. (This assumes that all the water in the concrete system can be dried out (highly unlikely), and then on immersion find its way back to completely fill all the voids). It is more likely an indicator of the permeability that is related to the density of the relatively large capillaries.

Using MIP (mercury intrusion porousimetry), Sadegzadeh(1987) explained that repeated power floating dramatically reduces the volume of pores down to a diameter of 0,1 µm. On the other hand they determined that there was an increase in pores ranging in size between 0,1µm and 0,01µm. However, pores of this size were relatively impermeable, as may be determined using ISAT.

They further found that abrasion resistance (rolling steel wheels) was a function of porosity, especially the larger pores. Mortars with low porosity were shown to have a high micro-hardness and high abrasion resistance. They observed that high w/b ratios led to high porosity.

Sadegzadeh(1986) defined initial surface absorption (ISA) as the rate of flow of water into concrete per unit area, over a stated interval of time, at a constant applied head and temperature.

The initial surface absorption test (ISAT) is a means of measuring the permeability of the very thin ‘skin’ of the concrete under investigation, since it relates to the moisture movement into the immediate surface layer. They found that the test was very sensitive to mix design, the effects of finishing technique and liquid surface treatments. An R^2

correlation coefficient of 0,94 was obtained between ISAT and abrasion resistance (where 0,81 may be regarded as highly significant).

They concluded that ISAT was closely correlated to abrasion resistance, and that it may well provide a basis for an indirect, non-destructive assessment of the insitu abrasion resistance of concrete.

The findings of other authors on ISAT have not been as positive:

Chaplin(1990) did experimental work using an ISAT, but concluded that it 'was not possible to make definite conclusions on the use of the ISA test' other that the test is sensitive to the curing regime.

Connel(1985) said that 'there appears to be a trend of increasing initial surface absorption with increasing abrasion loss (from sliding fine abrasive), however, the correlation could not be regarded as conclusive'.

13.1.2 Scope and Rationale

In earlier chapters of this volume a number of tests were used to define the various properties of concrete pavers, e.g. compression tests, tensile splitting tests, abrasion tests etc. These attributes were shown to be dependant on the density, which in turn is directly related to %voids/porosity, which in turn will have a strong influence on water absorption.

However absorption is more correctly a function of permeability, since concrete that has a high porosity will not necessarily have a high permeability, if the capillaries/voids are not interconnected (e.g. some air entrained concrete). On the other hand high porosity generally equates to a low density which negatively influences abrasion resistance. Thus, while porosity in the form of non-continuous voids has minimal influence on absorption, it significantly reduces abrasion resistance. On the other hand continuous capillaries also reduce abrasion resistance, *and* they significantly *increase* absorption. This inconsistency is likely to limit the usefulness of absorption determinations as a substitute for abrasion testing. While Sadegzadeh(1986) found a positive relationship between ISAT and abrasion resistance, the findings of Connell (1985) and Chaplin (1990) were inconclusive.

Given these different conclusions, this chapter examines such relationships as may exist between water absorption and (1) compressive strength, (2) density and (3) abrasion resistance (which receives special attention).

Two types of absorption tests, ASTM C140 and SABS 0164, are evaluated. Both tests are non destructive.

ASTM C140 is a measure of the absorption of the whole block, and may therefore be best suited to indicating bulk properties of the specimen such as its compressive strength and density. On the other hand SABS 0164 measures the initial surface absorption, and specifically gives information on the top few millimetres. This is exactly the zone of abrasion attack and the test may therefore be ideally suited for measuring abrasion resistance. The test can be compared with other initial surface absorption tests (ISAT) used by authors such as Chaplin(1987) and Connel(1985).

The extend to which cbp absorbs water is also important from a water proofing point of view. The writer has observed (in some extreme cases) paving blocks that are so porous that there is no run off when water is poured from a cup onto the face of the block. Porosity of this nature is most undesirable for the underlying structural layers.

From an aesthetic standpoint, porous blocks are also undesirable as they stand out from the rest, retaining a wet / dark look after rain, and it only takes a few of these blocks to spoil the appearance of a paved surface.

13.2 Description of Tests

13.2.1 ASTM C140

Origin of test

The specification, first published in 1938, covers compression as well as absorption testing.

Description

This test is described in 4.9 and briefly summarised here.

The test consists of weighing a saturated block, then drying to constant mass. The % absorption is calculated from the difference in mass between the saturated and oven dry masses, divided by the oven dry mass.

Limiting Criteria

ASTM C936 - 82: Standard Specification for Solid Concrete Interlocking Units states that the average absorption of the test samples shall not exceed 5% and the maximum individual absorption may not exceed 7%.

13.2.2 SABS 0164

This specification, in use locally since 1980 covers a wide range of requirements for the use of structural masonry including initial absorption of water.

Description

The test is described in 4.10 and is therefore only briefly summarised here.

Essentially the test consists of oven drying the block to constant mass. Next the specimen is cooled to room temperature, weighed, and placed in a special water tray such that the surface of the block is submersed in 3 mm of water. After one minute the block is removed, surface dried with a damp towel and reweighed.

The initial surface absorption is calculated from the difference between the two masses thus obtained divided by the dry mass.

Limiting Criteria

No criteria are defined in the specification.

13.3 Laboratory Test Results - 1987

For each of the 48 mixes, six blocks were selected and subjected first to ASTM C140, and then SABS 0164. The results are comprehensively given in appendices K.1 through K.8, and summarised in table 13.1.

Table 13.1 is constructed from the various appendices and is a summary of the density, compressive strength, and various abrasion indices for the 48 mixes of this investigation. From this table a number of graphs have been plotted (figures 13.1 through 13.15) illustrating the various relationships between water absorption (both ASTM C140 and SABS 0164 methods) and dry density, compressive strength, and the indices of the three abrasion tests.

TABLE 13.1 CORRELATION OF ASTM-C140 ABSORPTION TEST AND SABS-0164 (ISAT) WITH "AVERAGE" COMPRESSIVE STRENGTH, DRY DENSITY AND ABRASION RESISTANCE

MIX	COMPRESSIVE STRENGTH				ABRASION WEAR			DRY DENS	WATR ABSRP	ISAT
	SABS 1058 MPa	ASTM C140 MPa	MA20 MPa	AVERAGE FOR THREE MIXES MPa	WIRE PCI TM 7.11 cm^3/cm^2	SAND ASTM C418 cm^3/cm^2	BALL MA20 Index	ASTM C642 kg/m^3	ASTM C140 %	SABS 0164 %
1.1	35.3	35.4	44.9	38.5	0.068	0.290	2.18	2308	1.50	0.06
1.2	36.6	36.1	45.8	39.5	0.085	0.276	2.30	2308	1.41	0.05
1.3	30.9	27.5	39.3	32.6	0.090	0.314	1.67	2266	2.18	0.09
1.4	22.0	19.0	28.4	23.1	0.145	0.392	0.99	2160	5.21	0.35
1.5	22.6	20.1	28.0	23.6	0.163	0.408	0.91	2159	5.80	0.40
1.6	15.9	16.4	22.0	18.1	0.149	0.443	0.70	2113	6.50	0.50
2.1	29.2	27.5	35.3	30.7	0.128	0.322	0.99	2283	1.85	0.08
2.2	30.3	27.6	36.0	31.3	0.105	0.312	0.93	2298	1.61	0.06
2.3	27.9	24.8	35.2	29.3	0.100	0.336	0.96	2242	3.09	0.10
2.4	23.9	18.9	26.2	23.0	0.132	0.481	0.67	2175	5.82	0.27
2.5	19.1	17.1	25.0	20.4	0.152	0.523	0.74	2110	7.54	0.40
2.6	18.0	14.7	21.6	18.1	0.162	0.509	0.68	2108	7.42	0.65
3.1	18.9	18.9	25.0	20.9	0.134	0.514	0.74	2188	3.54	0.07
3.2	15.9	18.5	22.8	19.1	0.145	0.478	0.55	2194	3.92	0.07
3.3	15.1	14.6	18.5	16.1	0.158	0.575	0.50	2109	6.99	0.24
3.4	12.5	12.0	16.6	13.7	0.187	0.607	0.40	2037	9.93	0.95
3.5	11.4	11.1	15.0	12.5	0.221	0.702	0.34	1995	10.44	1.70
3.6	11.9	11.8	16.6	13.4	0.187	0.686	0.38	2016	10.03	1.39
4.1	25.4	26.1	32.3	27.9	0.125	0.349	0.84	2243	3.52	0.08
4.2	28.1	26.3	32.9	29.1	0.096	0.370	0.86	2259	2.90	0.07
4.3	16.4	15.6	20.2	17.4	0.157	0.417	0.48	2121	6.61	0.34
4.4	14.3	14.5	19.4	16.1	0.211	0.426	0.43	2110	6.53	0.41
4.5	15.5	14.3	21.3	17.0	0.204	0.601	0.46	2117	6.52	0.35
4.6	13.4	14.3	19.5	15.7	0.164	0.662	0.42	2076	7.80	0.51
5.1	29.9	29.2	37.9	32.3	0.108	0.384	1.28	2267	3.15	0.06
5.2	22.7	27.0	30.0	26.6	0.129	0.390	1.28	2230	3.63	0.07
5.3	19.8	18.3	24.0	20.7	0.137	0.451	1.04	2170	5.36	0.18
5.4	19.3	20.2	25.0	21.5	0.137	0.410	0.93	2202	4.53	0.15
5.5	18.2	17.2	21.0	18.8	0.162	0.482	0.54	2102	7.02	0.41
5.6	13.7	12.1	16.5	14.1	0.226	0.645	0.39	2055	8.16	0.79
6.1	28.6	30.2	34.7	31.2	0.102	0.437	0.95	2242	4.20	0.06
6.2	27.2	28.1	32.9	29.4	0.093	0.401	0.89	2220	3.50	0.06
6.3	22.1	23.2	24.4	23.2	0.150	0.587	0.77	2166	5.36	0.18
6.4	16.4	19.2	22.6	19.4	0.155	0.591	0.55	2121	6.51	0.26
6.5	14.0	16.4	19.6	16.7	0.147	0.598	0.44	2058	8.15	0.64
6.6	12.3	11.3	16.7	13.4	0.156	0.596	0.37	2021	9.27	1.16
7.1	31.6	33.2	42.3	35.7	0.105	0.320	1.50	2286	1.52	0.06
7.2	26.1	29.1	39.8	31.7	0.106	0.346	1.55	2263	2.04	0.07
7.3	23.0	21.9	32.0	25.6	0.114	0.385	0.98	2208	3.88	0.18
7.4	20.1	23.4	31.0	24.8	0.112	0.413	1.20	2175	5.06	0.29
7.5	20.0	16.3	26.3	20.9	0.124	0.453	0.77	2110	7.24	0.64
7.6	16.0	13.5	21.1	16.9	0.152	0.507	0.48	2073	7.86	0.83
8.1	28.6	32.6	40.2	33.8	0.087	0.326	1.60	2262	1.54	0.05
8.2	32.1	30.4	42.4	35.0	0.103	0.338	1.80	2279	1.42	0.05
8.3	31.1	31.7	43.6	35.5	0.084	0.359	1.73	2285	1.41	0.05
8.4	24.0	18.9	28.8	23.9	0.117	0.472	1.26	2103	6.79	0.60
8.5	18.1	21.1	27.8	22.3	0.137	0.475	1.00	2100	6.77	0.69
8.6	17.8	18.2	25.0	20.3	0.156	0.444	0.68	2092	7.03	0.61
AVG	21.7	21.4	28.2	23.8	0.14	0.45	0.92	2168	5.21	0.36
R^2 w.r.t. Water Absorption ASTM C140				0.853	0.674	0.764	0.631	0.970		
R^2 w.r.t. ISAT SABS 0164				0.533	0.487	0.550	0.686	0.754		

13.3.1 Relationship between absorption and density

The relationship between water absorption and dry density is demonstrated in figures 13.1 through 13.3 respectively for mixes with 18 %, 14 %, and 10 % binder content. The ASTM C140 and SABS 0164 results are plotted on separate Y-axes.

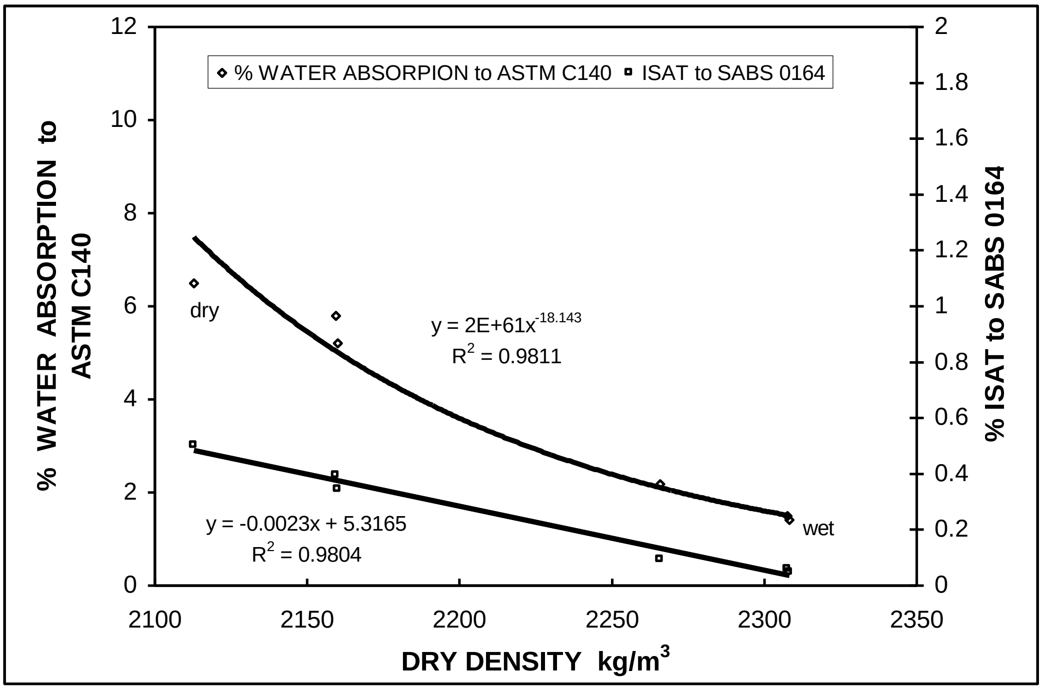

Figure 13.1 Relationship between dry density and (1) water absorption to ASTM C140 and (2) SABS 0164: **Mix 1: 9% OPC, 9% MGBS**

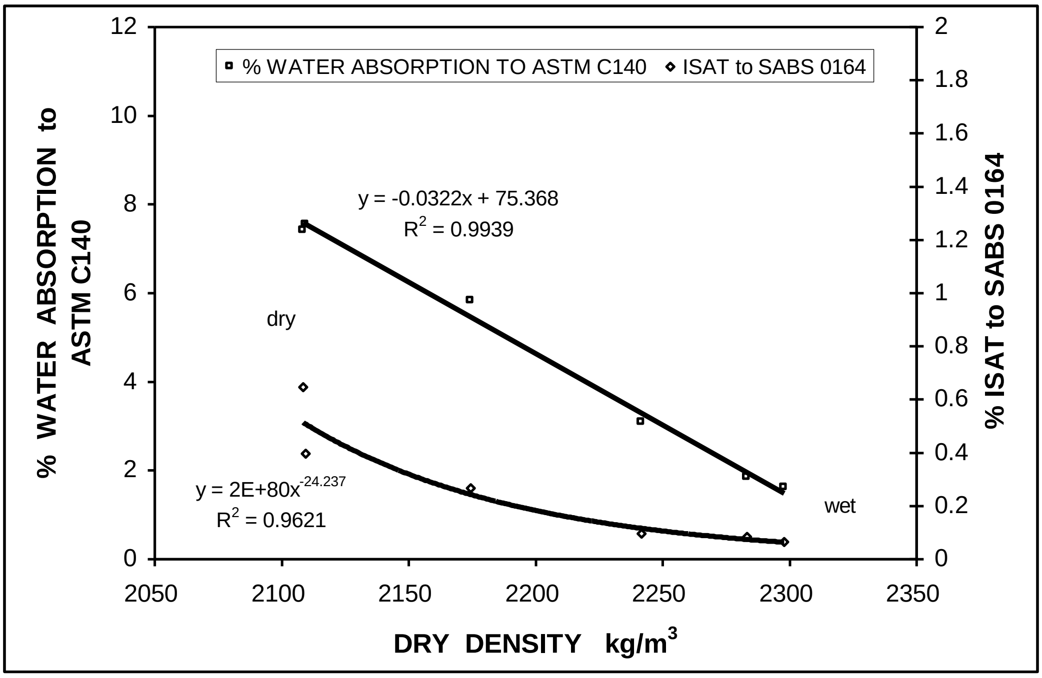

Figure 13.2 Relationship between dry density and (1) water absorption to ASTM C140 and (2) SABS 0164: **Mix 2: 7% OPC, 7% MGBS**

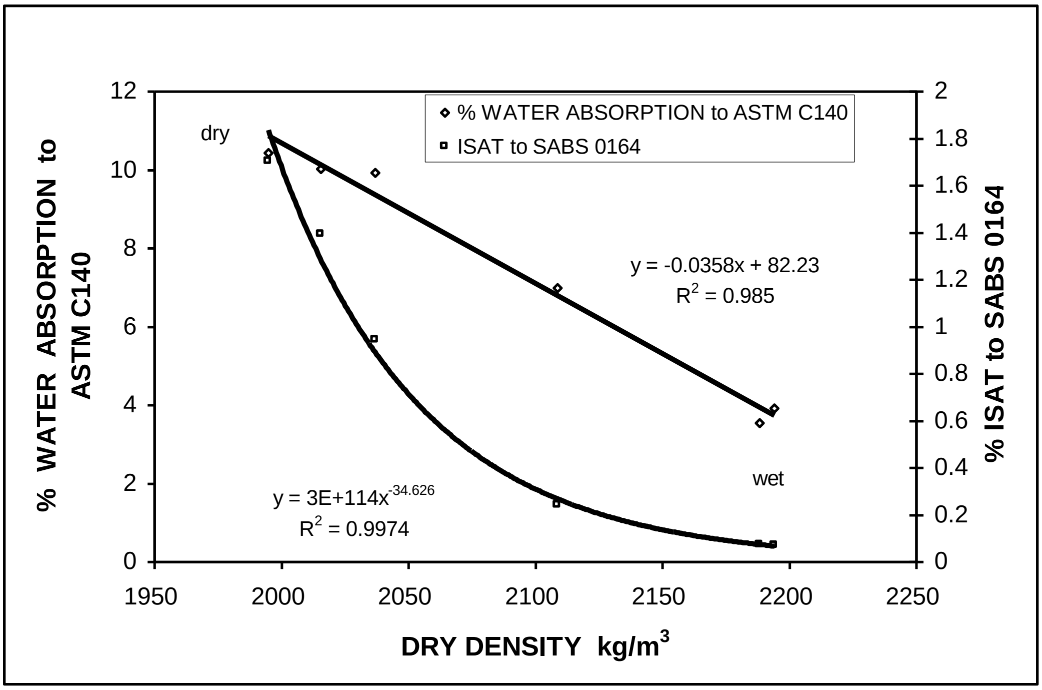

Figure 13.3 Relationship between dry density and (1) water absorption to ASTM C140 and (2) SABS 0164: **Mix 3: 5% OPC, 5% MGBS**

From these graphs a number of comments can be made:

a Wet mixes have greater densities than dry mixes.

As may be expected, the corresponding water absorptions are much lower for wet mixes relative to dry mixes, for any given binder content. This applies to both the ASTM C140 and SABS 0164 results. In the case of the ASTM C140 test, a loss of approximately 10% in density from ‘wet’ to ‘dry’ translates to a very high increase in absorption, in the region of 300 %. In the case of the ISAT test this figure can be as high as 1000 % or more.

The through-block absorption is linearly related to density. On the other hand surface absorption increases exponentially as density decreases, accounting for the large ISA difference between pavers from ‘dry’ and ‘wet’ mixes. The respective linear and exponential expressions are shown in the three graphs, and R^2 values ranging from 0,962 through 0,997 indicate how well the experimental data fits these expressions.

The writer is unable to explain why the ratio $\text{absorption}_{\text{dry-mix paver}}$ / $\text{absorption}_{\text{wet-mix paver}}$ should be different for the two tests, nor why ASTM C140 absorption is linear with respect to density while ISAT 0164 is exponential.

Figures 13-1 through 13-3 are nevertheless remarkable illustrations of how the extra water in wet mixes facilitates compaction and density, reducing absorption. Evidently the macroscopic capillaries and hollow spaces are closed off to a large extent limiting absorption very noticeably (and vice versa for the blocks from dry mixes).

b The binder content also plays an important role in the water absorption.

ASTM C140: Considering the two wettest mixes together in figure 13.1 through 13.3, the wet mixes have water absorptions of 1,5 %, 1,7 % and 3,7 % in the case of the respective 18 %, 14 % and 10 % binder contents. The corresponding water absorptions for dry mixes are 6,1 %, 7,4 % and 10,2 %. These relationships are further illustrated in figure 13.0A.

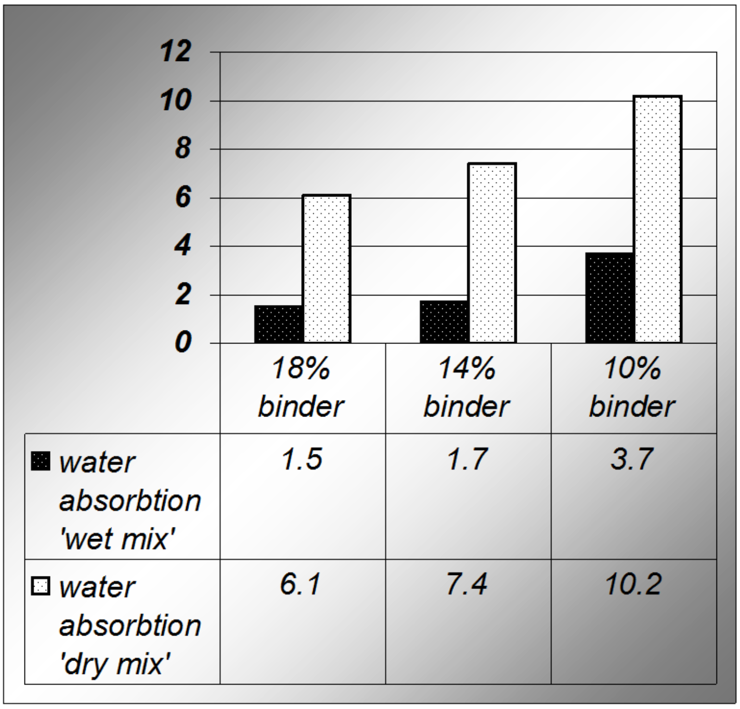

Figure 13.0A Effect of binder content on water absorption (ASTM C140) for ‘dry’ and ‘wet’ mixes

There is therefore an increase in water absorption as binder content is reduced, particularly at the level of 10 %, and this applies to both ‘wet’ and ‘dry’ mixes. This is because a low paste content requires a high water/binder ratio, the additional water being required to facilitate compaction. This additional water translates into additional capillaries/pores/voids, increasing porosity in the hardened binder paste. If on the other hand, the w/b ratio is not adjusted upwards, entrapped air will not be expelled during vibration, and this clearly also amounts to increased porosity. Conversely, where mixes have high proportions of paste, full compaction may be achieved with w/b ratios as low as 0,2 (this is discussed in some depth in chapter 2 of volume 2 - the high proportion of paste compensates for its high viscosity).

SABS 0164: Similar tends as above, except that the % absorption is far less than ASTM C140, given that the block only has its surface placed in the water for one minute.

13.3.2 Correlation of water absorption with density and compressive strength

The correlation between water absorption (both ASTM C140 and SABS 0164) and density may be seen from figures 13.4 and 13.5, while the correlation between water absorption and compressive strength may be seen from figures 13.6 and 13.7. Note that it is the ‘average of 18 blocks’, representing the averages of the three compression tests that is used here for each point plotted.

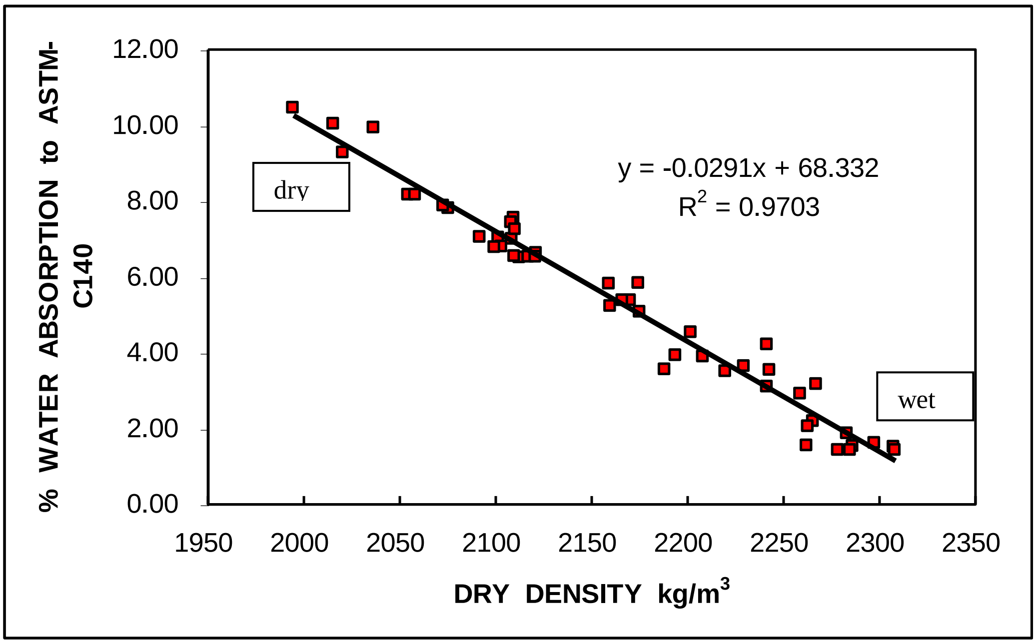

Figure 13.4 Correlation between ASTM C140 water absorption and dry density

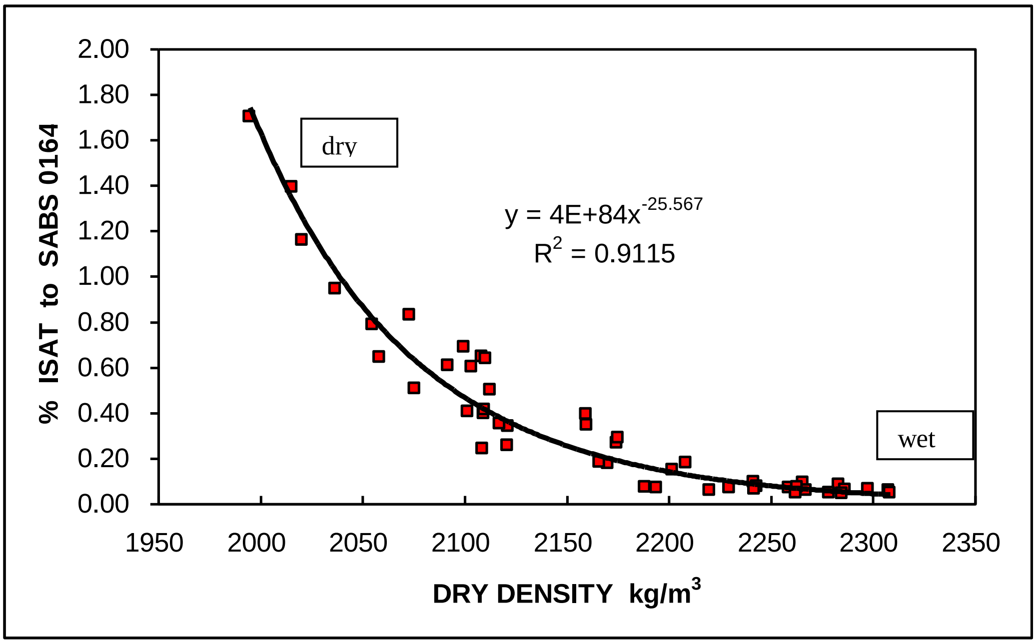

Figure 13.5 Correlation of ISAT (SABS 0164) and dry density

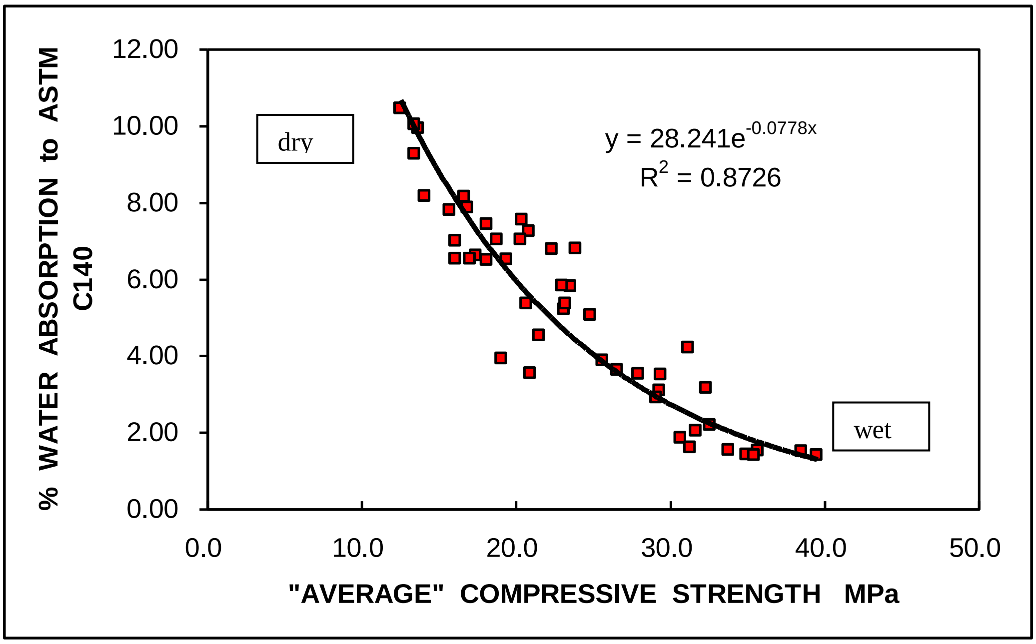

Figure 13.6 Correlation between ASTM C140 water absorption and 'average' compressive strength

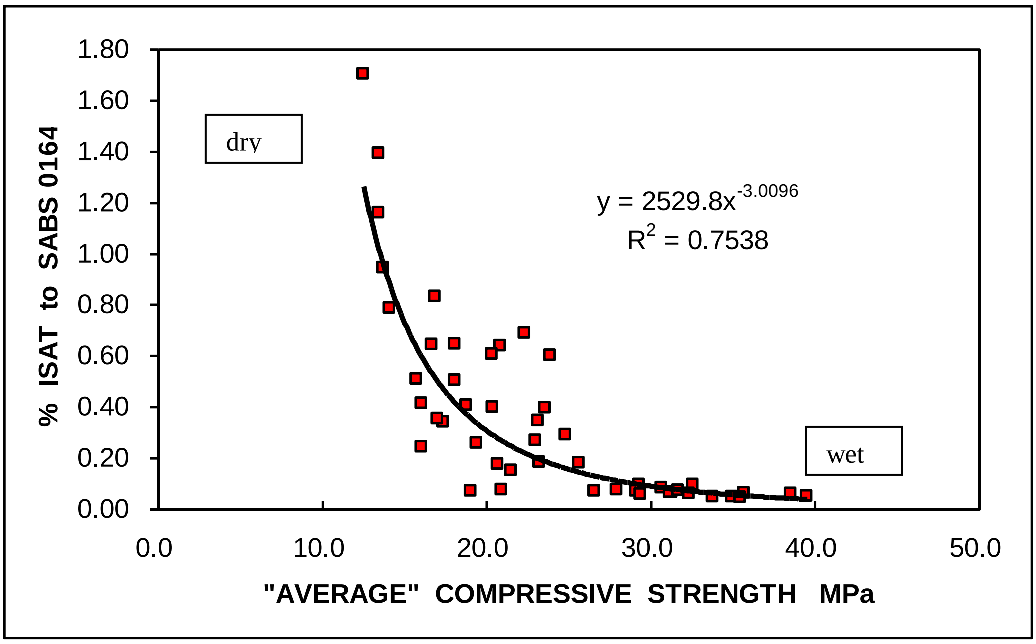

Figure 13.7 Correlation between ISAT SABS 0164 and 'average' compressive strength

From these graphs and table 13.1 a number of comments can be made:

a The linear correlation between water absorption and dry density for the 48 mixes is excellent, with $R^2 = 0.97$. The exponential correlation between water absorption and compressive strength is good, with $R^2 = 0.873$.

The linear correlation between ISAT and dry density for the 48 mixes is very good, with $R^2 = 0.912$. The exponential correlation between ISAT and compressive strength is reasonably good, with $R^2 = 0.754$.

Both dry density and compressive strength are representative of the bulk properties of concrete, and are not necessarily accurate indicators of the surface quality. This is even more the case where poor surface curing prevailed or for blocks made with surface concrete with excessive voids, as may occur when a separate topping is applied to pavers etc. These two problems did not however apply in this investigation. It is therefore somewhat surprising to note that while the relationship between through-block absorption and density is linear, that of ISA is exponential. The difference in scale is understandable, but the writer has no explanation for the acceleration in ISA with decreasing density.

b Blocks greater than 27 MPa all have very low ISAT values (say less than 0,1% kg/kg/min, see table 13.1, or figure 13.7).

Table 13.1 also reveals that these mixes are ‘wet’ mixes and may be summarised as follows:

7 out of 8 of the wettest mixes
7 out of 8 of the second wettest mixes
3 out of 8 of the third wettest mixes (mix 1, 2, and 8)

It is interesting to note that the two other low points on the y scale (figure 13.7) apply to the wettest and second wettest mixes of mix design 3, which only had 10% binder, although here the compressive strength was less than 27 MPa.

Thus wet mixes irrespective of binder content have low ISAT values, indicating that they are relatively impermeable.

The fact that all mixes with low ISAT values that had binder contents of 14% (and more) all had a compressive strengths that exceeded 27MPa, suggests that the SABS 0164 test can be used as a kind of guarantee of ‘minimum compressive strength’. This may have useful applications for testing large samples on a pass-fail basis, given that the test is fast and non-destructive. The only proviso is that the quantity of binder must be known, since blocks made with 10% binder and compressive strengths of 20MPa will also ‘pass’ if they are made very wet.

13.3.3 Correlation of water absorption with abrasion resistance

Figures 13.8 through 13.13 correlate the two absorption tests with each of the three abrasion tests. In each case the ‘average’ (average of five blocks for the sandblast test and MA20 test, and average of 4 blocks for the wire-brush test) has been used for each of the 48 plotted points (see table 13.1).

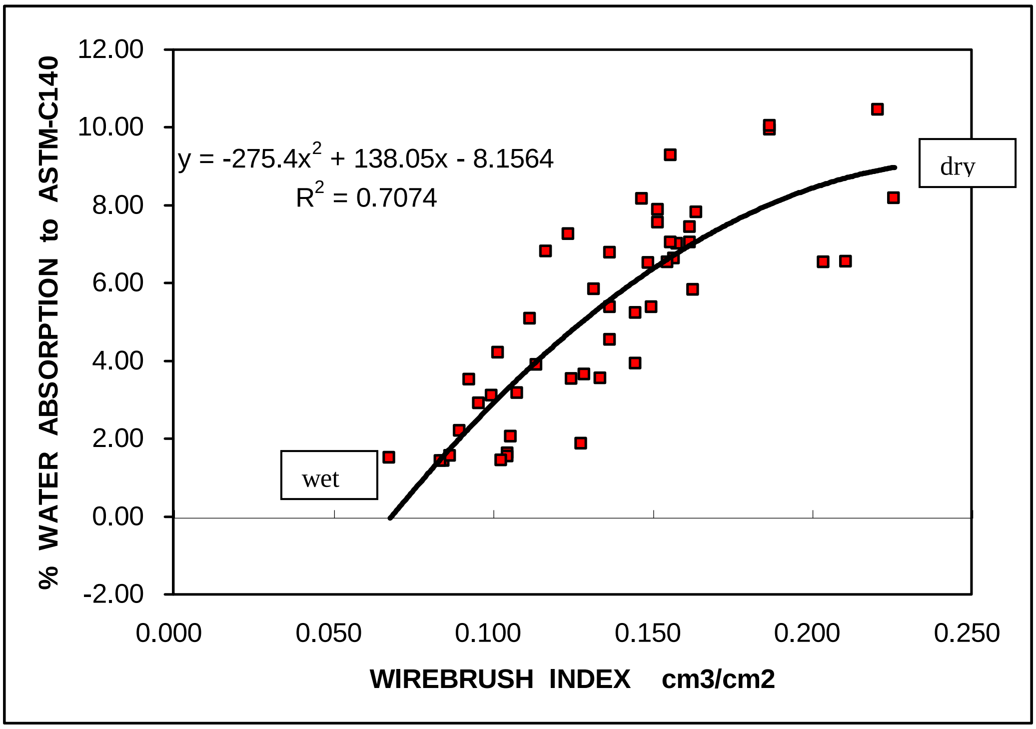

Figure 13.8 Correlation of ASTM C140 with wire-clay abrasion-wear index.

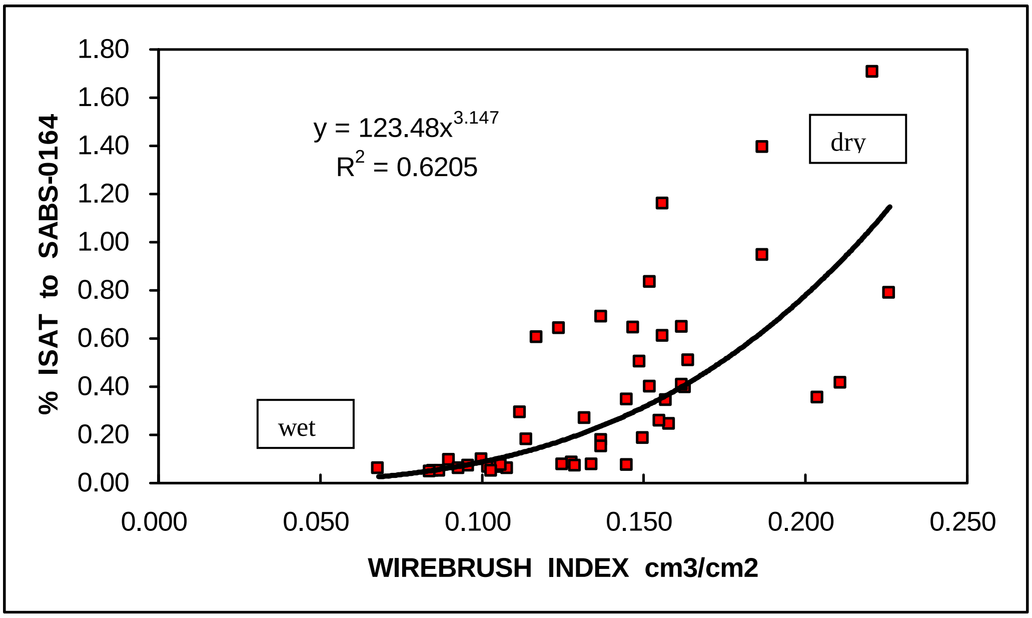

Figure 13.9 Correlation of ISAT with wire-clay abrasion-wear index.

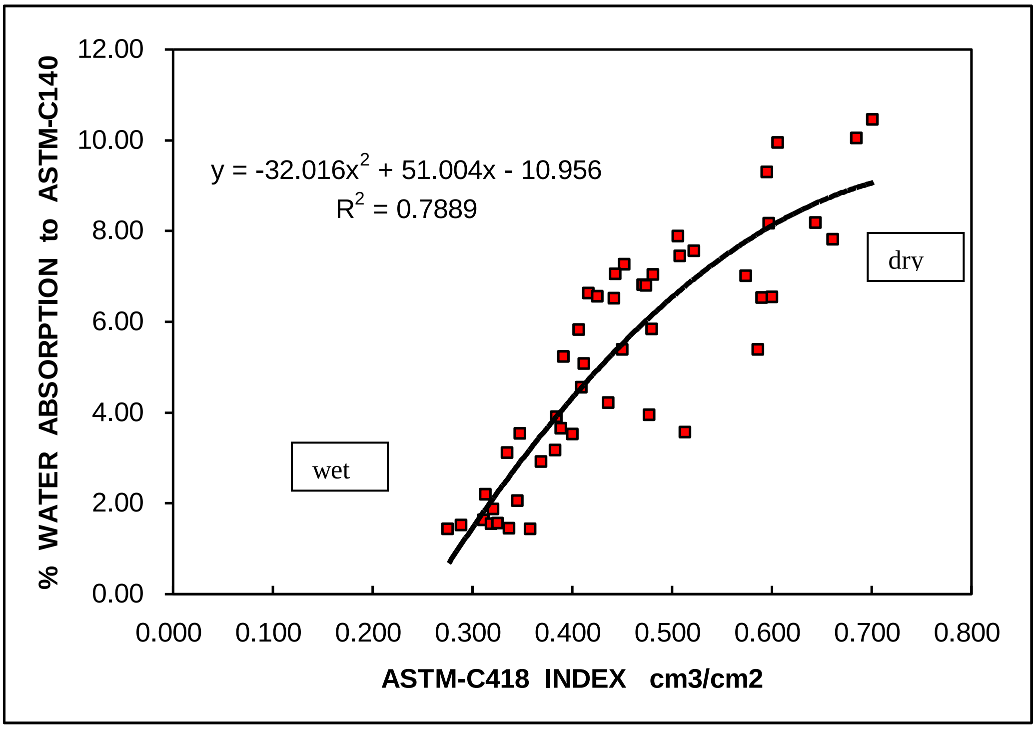

Figure 13.10 Correlation of ASTM C140 with ASTM C418 abrasion-wear index.

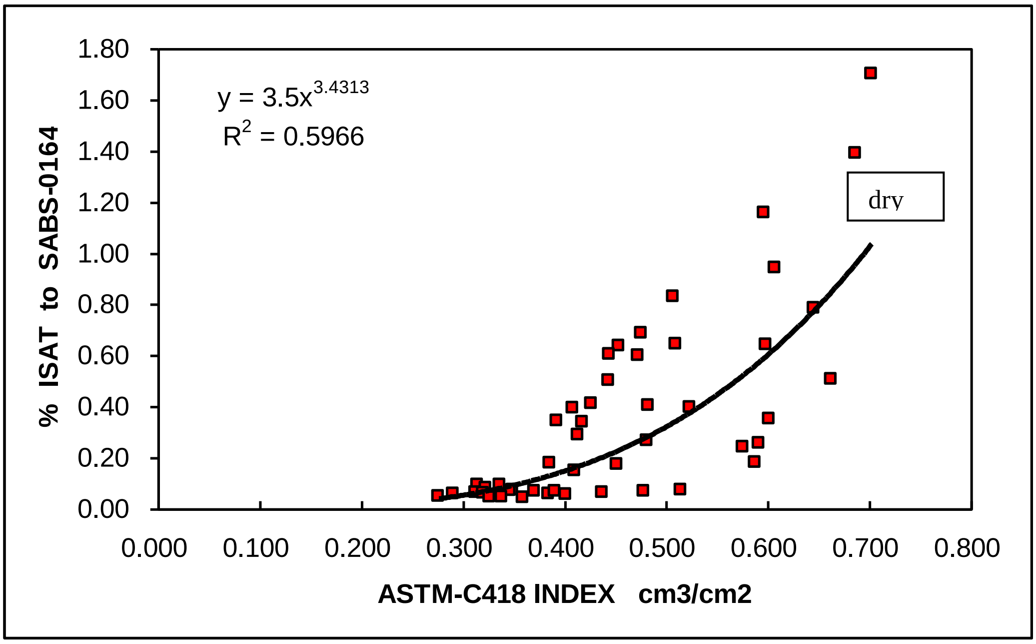

Figure 13.11 Correlation of ISAT with ATM C418 abrasion-wear index.

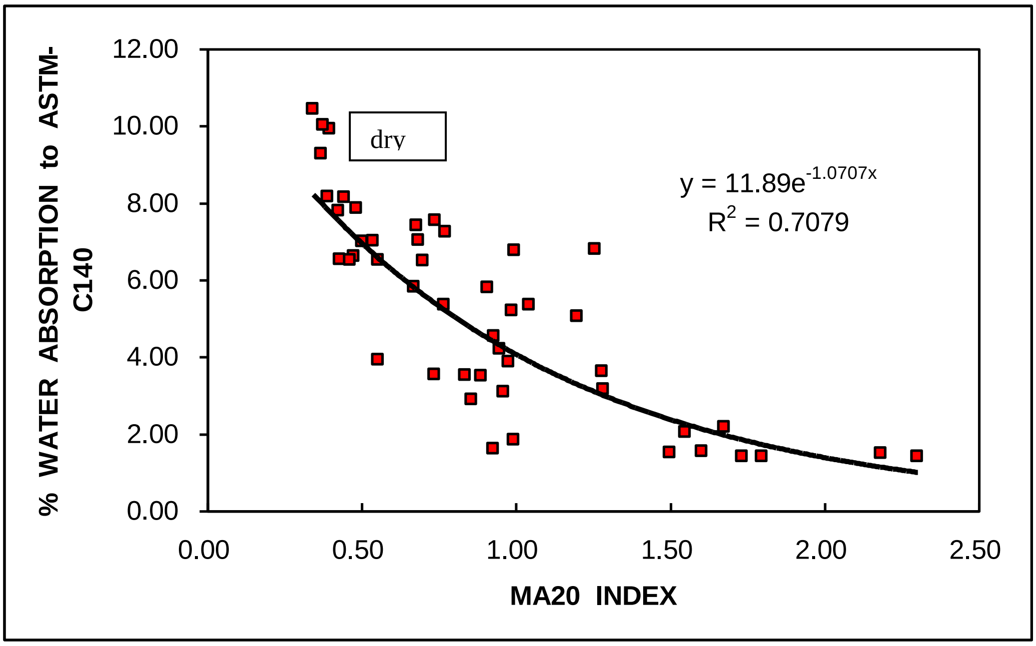

Figure 13.12 Correlation of ASTM C140 with MA20 abrasion index.

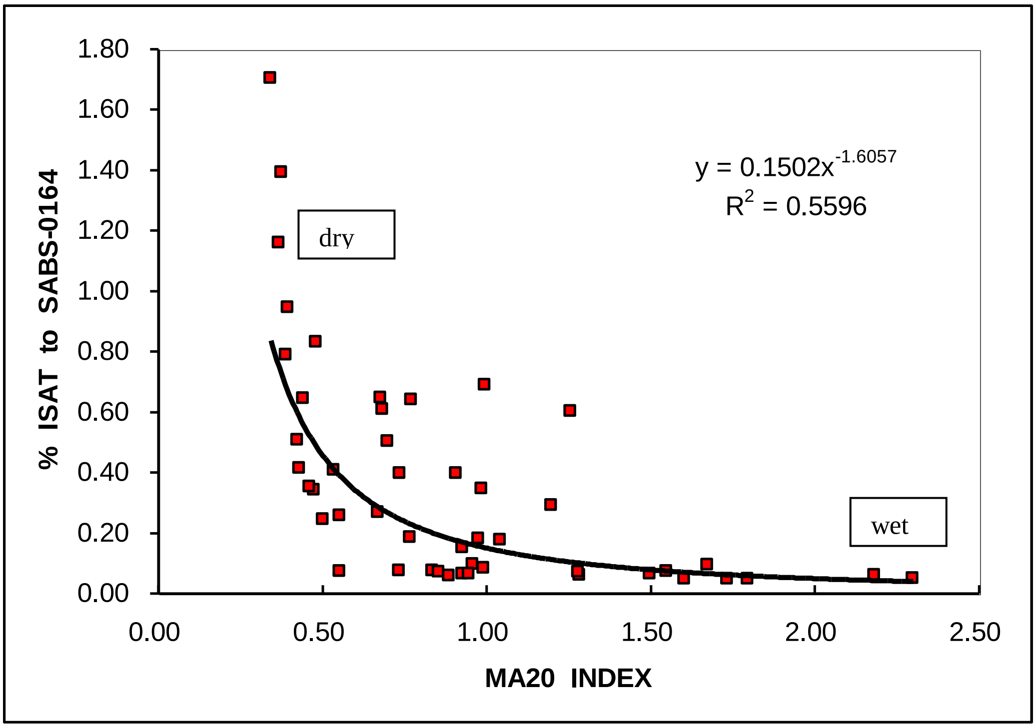

Figure 13.13 Correlation of ISAT with MA20 abrasion index.

From these graphs a number of comments can be made:

a R² values of 0,707, 0,789 and 0,708 in figures 13.8, 13.10, and 13.12 indicate a reasonable polynomial trend between wire-brush and sandblast abrasion resistances and absorption per ASTM C140. In the case of the MA20 indices, an exponential trend line best fits the data. Clearly through-block absorption does not correlate as well with the abrasion tests as it does with bulk tests, (i.e. compressive strength and density, see 13.3.2), confirming that a bulk indicator such as through-block absorption is not a suitable substitute for a surface test. Moreover, the correlation obtained in these graphs would in all probability be far worse if the tight manufacturing controls on surface curing and face concrete had not been enforced in this programme.

b The less-that-good R² values of 0,621, 0,597 and 0,560 in figures 13.9, 13.11 and 13.13 indicate a relatively weak exponential correlation between ISAT and abrasion wear. For mixes above a certain abrasion resistance threshold the ISAT values are virtually constant, whereas a large scatter is apparent for mixes of lower abrasion resistance. It would therefore appear that this test is not the most ideal indicator of the abrasion resistance of cbp.

That ISAT should be better related to the bulk tests (density and compressive strength) rather than to the surface abrasion tests is most surprising, and once again the writer can offer no explanation.

It is also apparent that this test is purely a measure of paste permeability/porosity and has no ability to measure the hardness of the aggregate, which is a key factor in abrasion resistance. (The wire-brush and sandblast tests also have this failing).

13.3.4 Relationship between water absorption and water content

Figures 13.14 and 13.15 plot the water absorption (to ASTM C140 and SABS 0164) for the two extremes of water content, (i.e. the two wettest and two driest mixes) for the eight mix designs.

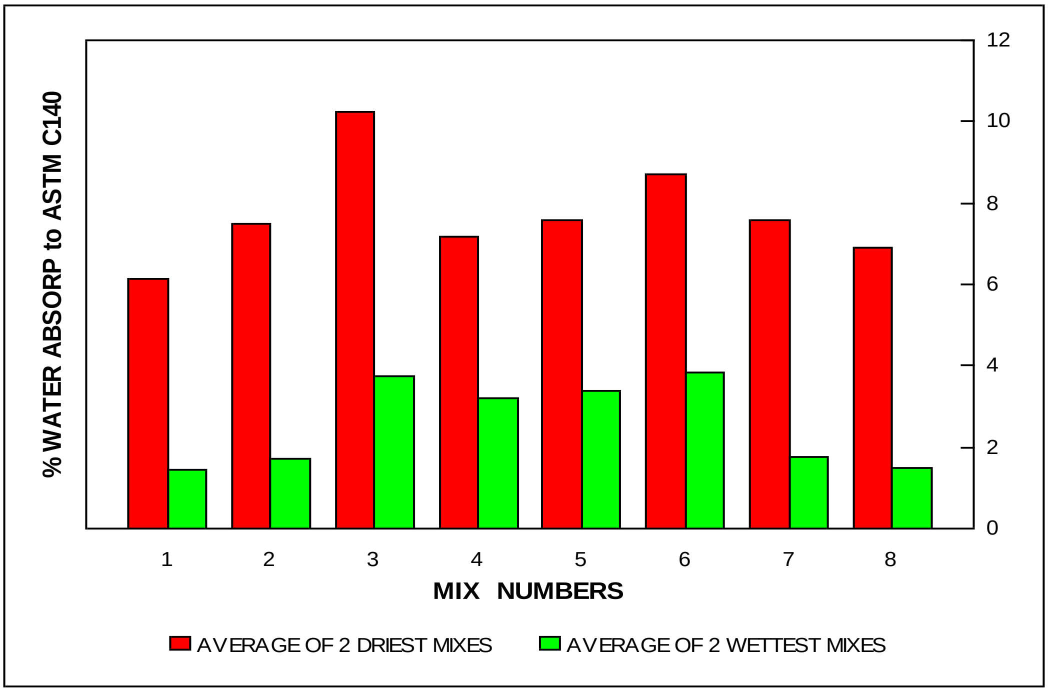

Figure 13.14 Water absorption to ASTM C140 for eight mix designs

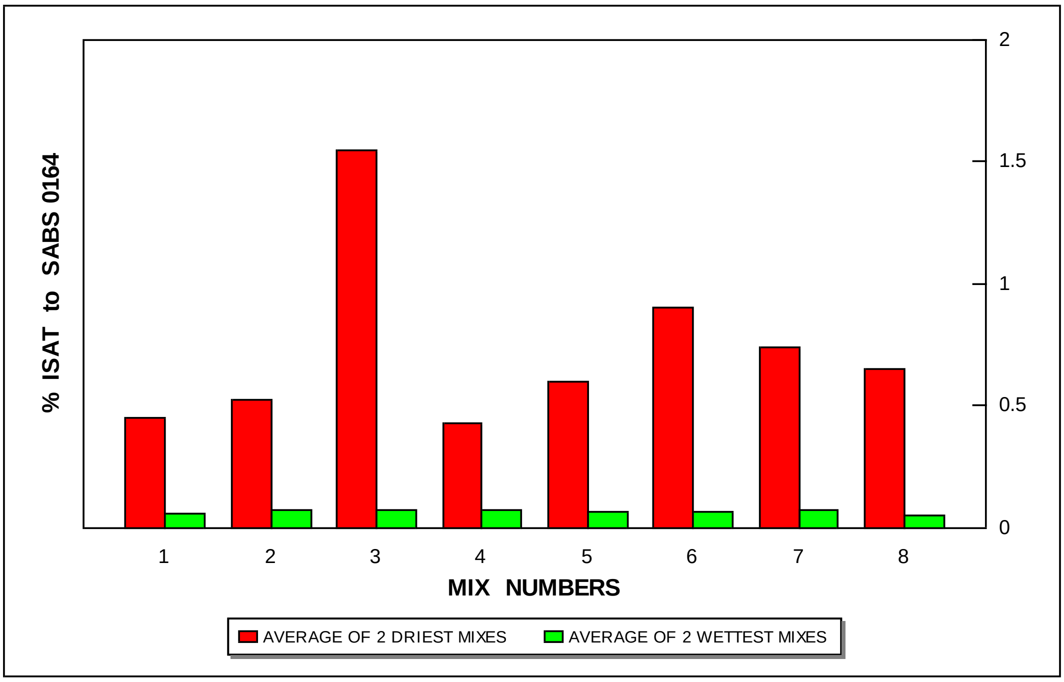

Figure 13.15 Initial surface absorption to SABS 0164 for eight mix designs

13.3.4.1 Water absorption to ASTM C140

The following trends emerge from figure 13.14:

a Compared to drier mixes, wetter mixes have significantly lower ‘bulk’ absorption values. ‘Dry’ mixes are generally from 120 % to 380 % more absorbent than ‘wet’ mixes.

b Comparing mix one (18 % binder), two (14 % binder) and three (10 % binder), it can be seen that mixes of higher binder content have lower absorption values.

c Comparing the six mixes of equal overall binder content, and considering only the ‘average of the 2 wettest mixes’, it may be seen that mixes two (containing 50 % MGBS), seven and eight (containing MGBS and SF), are significantly lower than mixes four, five, and six (containing FA). From this it would appear that MGBS and SF reduce the water absorption of cbp, relative to a combination of OPC and FA.

This pattern does not apply to the ‘average of 2 driest mixes’, where no clear trend emerges, with water absorption values ranging between 7 % and 9 %.

d Providing care is taken to make wet mixes it is possible to achieve water absorption values less than 4 %, regardless of binder type. Note that ASTM C140 allows no more that 5% (average) for freeze/thaw considerations.

13.3.4.2 Initial surface absorption to SABS 0164

The following trends emerge from figure 13.15:

a Compared to drier mixes, wetter mixes have *very* much lower ‘surface’ absorption values. ‘Dry’ mixes are generally from 500% to 2000% more absorbent than ‘wet’ mixes.

b The initial surface absorption, in the case of the ‘average of 2 wettest mixes’ is almost the same, regardless of the type and content of the binder, and is less than 0,1 %.

c Dry mixes with low binder contents have significantly higher ISAT values. This is demonstrated by mix 3.

Generally the filler sand between the blocks consists of very fine sand particles, detritus, oil spills etc., and has the potential to effectively seal the surface water runoff. Clifford(1984) has shown that providing the correct jointing sand is used, and assuming the density of the blocks renders the blocks virtually impermeable, the ingress of water into the supporting layers is so minimal that the block pavement can for all practical purposes be regarded as watertight. Shackel(1990) explained that in a cbp pavement the blocks themselves can be regarded as being impermeable, and that water can only penetrate the pavement via the joints, and then only in the early life of the pavement prior to the joints becoming clogged with sand detritus and oil. Thus in the long term the block pavement ‘can be regarded as being largely impermeable’.

These assertions naturally are based on the assumption that the blocks are not unduly permeable. The ISAT test may thus be useful as a simple test for confirming the ‘waterproofing’ ability of the actual pavers themselves.

In conclusion, figure 13.15 indicates excellent ISAT values providing care is taken to make wet blocks.

13.4 Strengths and Weaknesses of Water Absorption Tests

ISAT & ASTM are important with respect to freeze/thaw resistance. Clearly by limiting the quantity of water in the pores the risk of damage is reduced. The 5% requirement of ASTM C 140 can be met quite easily by optimising the water content of the mix. (In semi-dry concrete this may be equated to using as much mix water as practically possible). The results of this investigation show that well lubricated mixes have water absorptions as low as 2% (table 6.2).

a Considering the length of time taken to dry the specimens to constant mass (a few days in a drying oven), the tests would not be ideally suited as a means of production control. With these tests it is therefore not possible to remove a block from a particular batch, apply the test, and obtain the result in the next 10 to 20 minutes, as is the case for the three abrasion tests.

b A drying oven and scale can be classified as moderately expensive, although most laboratories of any significance will have both these items in which case no outlay of equipment is required.

c It is inexpensive on a test-by-test basis, as far as abrasive medium is concerned. The major cost would lie in electricity consumption required to keep the oven at constant temperature.

d Both tests are existing standards, so that results can be compared with work done elsewhere. However the author has no knowledge of any country where these tests have been officially adopted for testing abrasion resistance.

e The repeatability of the ASTM C140 and SABS 0164 absorption tests are indicated by their respective ‘average of 48’ coefficients of variation of 10.4% and 25.5% respectively in table 12.4. The SABS 0164 is of the same order as the MA20 test (24.3%), whereas the ASTM C140 absorption test is better than the Wire-brush at 15.1% but worse than the ASTM C418 test at 7.7%.

Compared to the three abrasion tests, the ISA test does not correlate as well with the compressive strength results of this investigation, indicating that it is less suitable for assessing abrasion resistance.

f The reproducibility of this test has not been confirmed in this work since only one test apparatus was used. However, since drying ovens and electronic scales are commonly made commercial items, the reproducibility is likely to be very good where care is taken to accurately control temperatures, airflows inside the oven etc.

g Sensitivity. Both tests are very sensitive, with ‘dry’ blocks showing very much higher absorptions than ‘wet’ blocks.

h In contrast to the three abrasion tests the two absorption tests are non destructive.

i Neither of the absorption tests is able to measure the strength/bond/hardness of the aggregate.

13.5 Conclusion

The *ASTM C140* absorption test relates to the bulk property of concrete rather than its surface condition, and is therefore not an ideal indicator of abrasion resistance of cbp.

It does correlate very well with density, and also has a good correlation with compressive strength. However since it is a time consuming test, it is unlikely to ever replace compression or density tests as a means of assessing the bulk properties of cbp, unless porosity is of particular concern, such as in paver lined canals, or paved roads in high rainfall areas.

The SABS 0164 initial surface absorption test is indeed a surface test. However correlation with the three abrasion tests is only of the order $R^2 = 0.6$, and it is therefore not an accurate indicator of abrasion resistance.

Probably the most serious drawback of absorption testing is that it cannot assess the contribution that aggregate hardness makes towards abrasion resistance.

These conclusions tend to support those of Connell(1985) and Chaplin(1990); they also did not find a strong relationship between ISA and abrasion resistance. Overall it seems that this test is not an ideal alternative/substitute for abrasion testing.

Finally absorption testing distinguishes between discontinuous voids and continuous capillaries. Voids minimally affect absorption; conversely capillaries rapidly increase permeability; whereas *both* capillaries *and* voids strongly influence abrasion resistance.