THE GREAT UNSEALING

A Perspective on PCC Joint Sealing

By

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"In the twenties hundreds of miles of concrete highway had been laid ..., and people had sat back and said, 'there, that's permanent. That will last as long as the Roman roads and longer, because no grass can grow up through the concrete to break it.' But it wasn't so ... and a crack developed and a little ice in the winter spread the crack, ...

Then the county maintenance crews poured tar in the cracks to keep the water out, and that didn't work, ..." (1)

John Steinbeck, 1947

ABSTRACT

The general mission of most transportation agencies is to assure a customer focus in the development and operation of a safe and efficient transportation system. The customers desire comfort, convenience, safety, and cost-effectiveness in a transportation system. Agency research must have the objective of addressing customer related issues and measuring benefits of importance to them. Accordingly, any joint and sealant research has to answer the question of <u>why</u> we seal and whether it is cost-effective. Joint and sealant studies of Portland Cement Concrete (PCC) pavements must address these simple issues: does joint sealing enhance total pavement performance, if so, is it cost-effective, if so, what sealant system should be used.

The Wisconsin Department of Transportation (WisDOT) has been studying the effect of PCC joint/crack sealing on total pavement performance for 50 years. By 1967 there was substantial documentation that filling and refilling of contraction joints had no beneficial effect on pavement performance. By 1984, it was concluded that pavements with unsealed joints had better overall performance (distress, ride, materials integrity) than pavements with sealed joints. In 1990, WisDOT passed a policy eliminating all PCC joint sealing (in new construction and maintenance).

This "no-seal" policy has saved Wisconsin $6,000,000 annually with no loss in pavement performance and with increased customer safety and convenience. The entire PCC sealing issue is beginning to be addressed at the national level, assuring no false assumptions, and with the customer’s needs in view.

MISSION

The mission of transportation agencies is generally stated in terms of providing leadership and a customer focus in the development and operation of a safe and efficient transportation system. Highway pavements are the backbone of most transportation systems and clearly represent the largest investment in funds, staff and resources. In order to meet an agency's mission these pavements must be managed with the customer's needs in view, capitalizing upon them in all rehabilitation, maintenance and investment activities.

In broad terms, the customer desires comfort, convenience and safety in a cost-effective transportation system. Comfort can be characterized as a quality ride, low noise, etc. Convenience is a function of congestion, lack of delays and longevity of pavement life. Safety relates to roadway obstructions, friction, and similar items. The issue of PCC joint sealing has to be scrutinized in relation to these customer driven factors. Sealing has to somehow enhance pavement performance (ride or longevity) and/or convenience and/or safety. In addition, joint sealing has to be cost-effective, i.e., the measured benefits have to exceed the costs (which include user delays and safety problems related to closing lanes to reseal joints).

AGENCY PERSPECTIVE

A strategy for pavement planning and management, based upon quality from the customer's perspective, is increasingly becoming the charge of transportation agencies. Agency personnel in the past have been concerned about things like adhesion and cohesion failures in sealants but the customers have no such concern. Customers do not care about water or incompressible materials getting into joints, unless water and incompressibles can be proven to negatively effect one of those issues listed above, e.g., ride or pavement life. Highway agencies are increasingly, and necessarily so, adjusting their priorities to coincide with those of the public in all maintenance, rehabilitation and research activities. Thus, agencies are approaching highway management in a more customer-driven, holistic fashion than in the past. This holistic approach to joint sealing research can be succinctly reduced to these simple issues:

1. Does joint sealing in any way enhance total pavement performance? Pavement performance is measured by total distress, life, ride (summer and winter), and materials integrity. Note: Pavement performance is not sealant performance. If sealed joints do not in any way enhance total pavement performance that is the end of the issue -- do not seal!

2. If joint sealing does somehow enhance pavement performance, then it is necessary to determine if the enhancement is cost effective. The cost-effectiveness has to include second saw cut costs, all sealing costs and all resealing costs for the life of the pavement, and user delay and safety costs due to resealing. Thus, it is not just enough to prove an enhancement in performance, the enhancement has to equal the costs. If joint sealing is not cost effective, that is the end of the issue -- do not seal!

3. If joint sealing is cost-effective, then it is appropriate to determine the best sealant system to use. Unfortunately, most past studies began and ended with this step. This step should only be considered after steps 1 and 2. Nationally there is still a dearth of information on items 1 and 2, because traditional research focused on step 3 (refining what sealant to use, measuring stress, sealant failures, etc.). If steps 1 and 2 are found to be true -- do seal!

RESEARCH PERSPECTIVE

Research has to proceed in an orderly fashion. Accordingly, joint and sealant research must concentrate on the primary issues (customer needs) and must not first focus on secondary issues (sealant performance). Until just recently, there were libraries full of information on sealant performance and the "how to's" of sealing, but the issue of total pavement performance, convenience and safety (the why do we seal issues) were virtually ignored. The state of the research art is changing, but until just recently observations and reports that are counter to traditional beliefs or assumed truths were steadfastly rejected or readily dismissed. As early as 1967, S.E. Hicks addressed the Highway Research Board concerning 20 years of observations which clearly showed the lack of benefits from joint sealing. Mr. Hicks further asked other agencies to study this subject.

"In closing I would like to urge that the many user agencies who conduct field tests each year to compare the effectiveness of competing joint sealants include on each experimental project a control section with unsealed joints. The cumulative results of reported observations over a period of the next five to ten years would be interesting and possibly quite enlightening. On the basis of our experience, the risk, as well as the cost, of providing such control sections would be quite modest". (2)

The urgings of S.E. Hicks were ignored.

In 1986, Karl Dunn ask that the TRB Committee on Joints and Sealants to seek presentations on the real issues of joint sealing. A great deal of credit is owed to Egon Tons and John Bugler (chairs of this committee) for allowing this. Based upon the presentations and a thorough literature search Dunn prepared a synthesis in 1987 in which he concluded:

"Basically, all the efforts and costs devoted to sealing and resealing joints in jointed PCC pavement is to achieve longer pavement life, or at least a higher level of service, that than expected for pavement with nonsealed joints. Unfortunately, the only documented evidence available concerning the possible realization of the longer or improved service attributed to sealing and resealing joints, are studies being conducted here in Wisconsin, and the results of these studies indicate there is *no difference* in measurable pavement performance". (3)

In spite of these efforts to initiate an objective evaluation of PCC joint sealing, until recently little objective research has been done in the United States. Researchers, academians and the highway agencies have failed to consider the true customer related issues, choosing rather to continue down the same traditional path. This path is unfortunately biased because there are no evaluations of total pavement performance and the basic tenant of providing non-sealed control sections is ignored.

Again, in early 1996 the Joint and Sealant Committee of TRB entertained presentations on why to seal joints or not seal joints. The results were the same as in 1986.

In late 1996 the weight of accumulating knowledge began to be recognized. The FHWA had sufficient justification to call for a national task group to evaluate the overall aspect of joint sealing. The above mentioned TRB Committee (chaired by Issam (Sam) Minkarah) forwarded a research proposal to the National Cooperative Highway Research Program asking for a full evaluation of PCC joint sealing from the holistic perspective. In addition, various agencies have began their own studies which include totally unsealed test sections.

ASSAILABLE TRUTHS

The need to seal PCC pavement joints/cracks is so ingrained in the United States pavement culture and is so seemingly sound from a theoretic perspective that it has been considered an unchallengeable truth. Those who have challenged it have been viewed as having conducted poor research or having some "axe to grind". This is not an indictment, but a lesson on how long standing assumptions eventually are elevated to "truths". The "truth" of keeping water and incompressibles out of joints may have had a basis when PCC pavements were built directly on the subgrade, but since the use of base courses the need to seal joints has not been proven.

The European's have an enlightened view. The 16th World Congress of the Permanent International Association of the Road Congresses in 1979 concluded that:

"... with joint spacings of 4 to 6 meters there is no disadvantage in leaving narrow transverse joints unsealed when

A) traffic is light,
B) traffic is heavy but climate is dry, and
C) traffic is heavy and climate is wet, but pavement is doweled." (4)

The conclusions of this International Congress support Wisconsin's research.

The underlying and guiding "truth" for research in the United States has been:

"Water and incompressibles must be kept out of PCC pavement joints/cracks in order to get good pavement performance".

This is an assumption! It has not been tested (except in Wisconsin, Europe and a few other cases) nor proven. Whether through brilliance or serendipity (actually the latter) WisDOT has tested this assumption and found it totally lacking merit. Over the years where this assumption has been tested by others the results have been the same. All research should pose the null hypothesis and include test sections in actual highways where there is no sealant (joints sawed as narrow as possible).

In Wisconsin, engineers used to believe that sealing was essential, and, it probably was when PCC pavements were placed directly on the subgrade. Then, in 1953, an incredibly fortuitous accident occurred. A jointed plain concrete pavement (JPCP), with a 12 meter contraction joint spacing (with 6 mm wide joints), was built on USH 151 in two contiguous counties (Lafayette and Iowa). In both counties the joints and cracks were filled with an asphalt based sealant at the time of construction. In Iowa County they were routinely refilled while in Lafayette County there was no refilling. After 11 years of service, and based upon pavement performance factors (faulting, cracking, spalling, patching, etc.) maintenance personnel concluded, "... it is quite apparent that the omission of the joint sealer resulted in better overall pavement performance than that of the sealed joints". This study indicated that efforts to keep some of the water and incompressibles out of the joint was of no benefit to overall pavement performance. Not only did this empiric observation defy common wisdom, it dared to state the inconceivable, that is, unfilled joints actually result in better pavement performance. This certainly peaked interest within the State on an otherwise mundane subject.

Based somewhat upon the above experience and that of several other pavements where joint filling at the time of construction had inadvertently been omitted, several iconoclastic engineers propounded an outrageous question. Is it actually necessary, they asked, to fill the contraction joints in PCC pavement? Their curiosity prompted a more systematic investigation of this subject.

Accordingly, in 1958 several test sections were placed in the southbound lanes of USH 41 in Washington County. This jointed reinforced concrete pavement (JRCP) had dowels. The joints were sawed 6 mm wide at 30 meter intervals and filled with hot-poured sealant conforming to ASTM D1190. One experimental section had filled joints, one had alternately filled and unfilled joints and another section had all unfilled joints. By 1966 the investigators were reporting that the condition of the unfilled joints was, "far superior," to the filled joints. Specifically, the unfilled joints exhibited less corner cracking and spalling than their filled counterparts.

In 1966 a second, larger experimental project was started on STH 78 in Columbia County. This seven kilometer stretch of pavement was very similar to USH 41 in design features, except that contraction joints were spaced at 24 rather than 30 meters. The joints in the southbound pavement were filled with a hot-poured sealant while the northbound pavement joints were left unfilled. It was also decided in 1966 to expand the objectives of the studies on USH 41 and STH 78, and, what had begun as a study of joint performance, became a study of pavement performance.

Based upon pavement distress, ride and materials integrity as evaluation criteria, it was concluded by Fred Ross in 1977 (one pavement being 19 and the other 11 years old) that,

"the inclusion or omission of a joint sealant at the time of construction has not exerted a significant influence on pavement performance". (5)

The above three studies were not the best designed research projects because they all had one glaring deficiency, i.e., the joints were not truly sealed nor could they be with the joint spacing, joint shape factor and sealants used. Thus, while these studies did clearly indicate that the effort to keep some of the water and incompressibles out of the joint was of no benefit, they did not answer the real question concerning the cost-benefit of truly sealed contraction joints.

The underlying assumption that supported joint sealing certainly seemed assailable. But were these early results reliable since these studies did not really evaluate truly sealed joints. What if they were truly sealed, would the results be different? While the WisDOT was certainly convinced in the early 1970's that "filled" joints were more harmful than helpful, a careful analysis of truly sealed joints was needed.

CHALLENGING THE ACCEPTED

"The primary factor in bringing about scientific discovery is not necessity or individual genius but the relentless pressure of accumulating knowledge."

Aaron J. Ihde

The pressure of accumulating knowledge was beginning to be relentless in Wisconsin. However, the nagging question remained, are water and incompressibles really an issue? One WisDOT researcher (Terry Rutkowski) observed that narrow unsealed joints are full of incompressibles (except for the top couple centimeters which are kept clear by traffic) but in warm weather (when the joint is narrow) water can not easily penetrate this fine material and in cold weather (when the joint is open) the base is frozen and will not allow water intrusion.

By the early 1970's there was a tremendous volume of research and information on PCC pavement joint sealing; however, the vast bulk of this research was on joint and/or sealant performance. There seemed to be a total lack of information available on overall pavement performance as influenced by joint sealing, the emphasis being placed on the secondary issue of sealant and joint performance. The "benefit" of keeping compressibles and water out of joints seems to have been accepted in total, without ever being verified.

Although the findings of the studies in Wisconsin were proactive, they certainly were not conclusive. The great advances in joint sealing theory and sealing materials, coupled with the research by other agencies on the benefits of close contraction joint spacings, compelled the State in 1974 to begin a study of pavement performance as influenced by sealed and unsealed contraction joints at various spacings. Accordingly, over 50 test sections were constructed from 1974 to 1988 in doweled and undoweled pavements; in pavements with subgrades varying from sand, to silt to silty-clay with varying traffic loadings; in rural and urban situations; on two and four lane roadways; on dense and open-graded bases; and with plain and reinforced pavements.

Five pavements will be briefly summarized in this report. These five pavements are typical of all such research in Wisconsin. Test sections are a nominal 300 meters long.

1. USH 51, Marathon County -- rural

    - JRCP constructed 1974 (dowels)
    - 6, 12, 18, 24 meter joint spacings
    - 22 test sections, some sealed some unsealed
    - five sealants
    - sand subgrade, dense base

2. USH 18/151 Iowa County -- rural

    - JPCP constructed in 1983 (no dowels)

- Random-skewed joints (5 meter average spacing)
- 7 test sections - some sealed some unsealed
- three sealants
- silt subgrade, dense base

3. STH 16/190, Waukesha County -- rural

- JPCP constructed in 1983 (no dowels)
- Random skewed joints (5 meter average spacing)
- 11 test sections - some sealed some unsealed
- three sealants
- silty-till subgrade, dense base

4. STH 29, Brown County -- rural

- JPCP constructed in 1988 (doweled and non-doweled)
- Random skewed joints (5 meters average spacing)
- Five test sections -- some sealed some unsealed
- One sealant
- Silty-clay-loam subgrade, dense base

5. STH 164, Waukesha County - urban

- JPCP constructed in 1988 (no dowels)
- Random skewed joints (5 meters average spacing)
- Six test sections -- some sealed some unsealed
- One sealant
- Silt/silty-clay subgrade, dense and open graded bases

The seals in USH 51 were kept perfectly intact for at least 10 years (the originally intended length of the study). Any significant sealant failures were corrected by resealing as soon as possible. The seals were allowed to deteriorate after 10 years.

Wisconsin summarized and published the 10 year findings for USH 51 thusly:

"When total pavement performance is considered, the results from 10 years of experience on USH 51 indicate that shorter joint spacings (say 6 meters) lead to better pavement performance than longer joint spacings. In addition, the pavement with unsealed joints performed better than the pavement with sealed joints. While the former result was expected and has been proven by other agencies, the latter result is provocative." (6)

"Arguments may be made to show why the sealed and unsealed test sections behave more similarly than the data show. However, such erudite efforts will be self defeating since they can only hope to prove, at best, equality of performance, but, performance equality is not enough. The entire costs for maintaining a sealed pavement for 10 years, i.e., from sawing a joint reservoir and sealing it to resealing the joint whenever it was needed, amounted to as much as 45% more than the cost for a similar unsealed pavement. Thus, to justify this cost one would have to prove either 1) a much greater serviceability (ride) during the pavement's life, 2) much less maintenance, or 3) a significant increase in pavement life. At this time and for this study, there is no basis for believing any of these three justifications is even possible, let alone true." (6)

Incidentally, blow-ups were a major problem in Wisconsin for pavements with 24 and 30 meter joint spacings. The use of closer joint spacings (5 - 6 meter) has virtually eliminated blow-ups. Blow-ups are not significantly influenced by joint sealing.

PERFORMANCE EVALUATIONS

The USH 51 study is presently 22 years old, the studies on USH 18/151 and STH 16/190 are 12 years old and the studies on STH 29 and STH 164 are eight years old. The seals on the latter four projects were not replaced once they failed. The total pavement performance evaluations, as a result of sealing or the lack thereof, are intriguing.

Distress

For a true measure of distress Wisconsin uses the Pavement Distress Index (PDI) which measures all distresses (extent and severity) and combines them into one index. Each distress is weighted to account for that distress' significance on pavement performance. The PDI scale goes from 0 to 100, with 100 being the worst possible.

In Figure 1, the trend is very obvious that the pavement in the unsealed test sections on USH 51 has less distress than in the sealed sections, for joint spacings of 12, 18, and 24 meters. For 6 meter joint spacings the results are curiously reversed. This reversal is indeed significant because it is the shorter joint spacings that are presently used in most states, including Wisconsin. By studying the 22 test sections on USH 51, in all cases but one, the performance of the unsealed sections is better than the sealed. The one unsealed test section has very anomalous behavior, accounting for this reversal. This anomalous test section had completely unique behavior from the time of construction -- it had significant joint spalling the first year. Fortunately we know why. The amount of spalling has nothing to do with the lack of a joint seal but it is the result of a construction problem. The reinforcing mesh was placed between two lifts of concrete and the mesh migrated during the placement of the second lift. Often this migration caused the mesh to cross the joint area. If the contraction joint sawing did not cut the mesh, the mesh caused joint spalling as the joint opened. This spalling occurred in other sections (mostly the short joint spacings) but was worse in this section than any other. FHWA and Minnesota evaluators independently arrived at this same conclusion.

This anomalous section could legitimately be removed from the study because of this mesh problem, but we want to be totally open and disclose all we can, so it is left in the evaluations. This (very worst) unsealed test section is shown in Prints 1 and 2. The first half of the test section is in nearly perfect condition at 22 years of age. The area with mesh problems, Print 2, shows joint areas that were repaired due to this problem.

To help resolve the issue of whether or not pavements with unsealed joints (in pavements with short joint spacings) have more distress than pavements with sealed joints the results from the other four test pavements are decisive, Table 1. The average distress index on these projects is less or equal for unsealed joints than sealed. This indicates that for pavements with short joint spacings there is less distress with unsealed joints than sealed.

A statistical analysis of PDI, comparing sealed and unsealed test sections (everything held constant except joint sealing), reveals there is no significant difference in PDI (95% confidence level).

Distress Conclusion:

Joint sealing has no significant effect upon pavement distress or life.

Ride

Another important factor in assessing total pavement performance is the ride experienced by the public. In fact, the public is more concerned about the ride they experience than the distress (an engineering concern). To assess the impact of joint sealing on ride the Wisconsin DOT measured the ride summer and winter on the test sections. The resulting International Roughness Index (IRI) scale goes from zero (perfectly smooth) to values over five (very rough).

On USH 51 the summer ride for the unsealed sections is slightly better than for the sealed, Figure 2. However, if sealing were to make a significant difference it should be during the winter in Wisconsin, when the water can get into the joints, freeze and then cause the pavement to tent at the joints. The winter ride readings, Figure 3, were significantly higher (worse ride) than the summer readings, but the unsealed and sealed sections had an equal ride.

The results of the ride readings for the other pavements, Table 2, were much the same as for USH 51. In all but one case, the unsealed test sections rode equal to or better than the sealed, both in summer and winter.

In Table 2, the ride on the undoweled pavements is much lower than the older doweled pavement on USH 51. The difference in ride is due to joint faulting. Interestingly enough, the joint faulting data often defies traditional wisdom with respect to joint sealing. For State Trunk Highways joint faulting is unacceptable when joints are not doweled, whether sealed or unsealed. Joints must be doweled.

JOINT FAULTING (undoweled)			
	Test Age	**Unsealed**	**Sealed**
USH 18/151	10	2.5 mm	3.8 mm
STH 16/190	10	4.8 mm	5.1 mm
STH 29	7	2.5 mm	2.5 mm
STH 164	8	3.3 mm	3.0 mm

A statistical analysis of pavement ride, comparing sealed and unsealed test sections, reveals there is NO significant difference in ride (at the 95% confidence level) as a result of joint sealing.

Ride Conclusion:

Joint sealing has no significant effect upon pavement ride qualities.

Bridge Encroachment

A total highway system analysis requires that the encroachment of the pavement on bridges be evaluated since unsealed joints may increase this problem. Wisconsin has traditionally provided several 25 mm expansion joints on both sides of a bridge to accommodate pavement expansion. After six years with a no-seal joint policy, district and central office bridge, maintenance and pavement structural design engineers were questioned about any changes in pavement expansion at bridges. All of these experienced personnel indicated there has been no change. This is not to say there are no encroachment problems, but that there has been no change since adopting a no-seal policy.

Encroachment Conclusions:

Joint sealing appears to have no observable effect upon bridge encroachment

Materials Integrity

In 1995 the USH 51 pavement was cored at random locations to determine if joint sealing had an effect on materials integrity. The cores had considerable variation but the general trend can be seen in Prints 3-6. Prints 3 and 4 were taken at sealed and unsealed joints with a 6 meter joint spacing. Generally the cores from pavements with short joint spacings had no distress. Prints 5 and 6 were taken at sealed and unsealed joints with a 24 meter joint spacing. The cores from pavements with long joint spacings generally had significant distress. Joint sealing had no effect on the distress at a joint; however, joint spacing did. The longer the joint spacing the more the distress. Again, blow-ups are a function of joint spacing, not joint sealing.

Materials Conclusions:

Joint sealing has no significant effect upon materials integrity.

INDEPENDENT VERIFICATION

In 1996 WisDOT's findings were verified by two independent teams from FHWA and Minnesota. The FHWA team included representatives from Washington DC, the Regional office and the Divisional office. Some on the FHWA team were skeptical of WisDOT's findings prior to a careful field review. The Minnesota team included personnel from the DOT, Concrete Paving Association and county government. Both of these groups independently and carefully reviewed one to several projects with sealed and unsealed joints. For USH 51 these teams had evaluations similar to that of WisDOT, Figure 1. These independent teams concluded that WisDOT has not biased any data or results to support a preconceived notion, and that for Wisconsin's test sections there is no difference in pavement performance as a result of joint sealing (if anything the unsealed sections are performing the best). Thus, joint sealing is not cost effective.

COSTS

On the USH 51 study, the 1974 cost to a create a sealed system (second saw cut, backing materia1, cleaning, and sealing) ranged from 8% to 22% of the square meter costs for a pavement with an unsealed system. When the costs for maintaining the joints in a sealed condition for 10 years were added, the pavement with sealed joint systems cost up to 45% more than the similar unsealed pavement.

Some newer sealants have a much larger extension range than the older sealants and sealing cost are lower now (percentage-wise). Assuming it would now cost $1.32 per square meter (for the second cut, cleaning, backer, and sealant), Wisconsin saves $2,800,000 dollars a year by not sealing newly constructed PCC pavement joints.

If we were to maintain a sealed system, the joints in existing pavements would have to be resealed, say every eight years. This resealing would amount to over 3,200,000 dollars annually.

Summing the above, it is clear that Wisconsin saves 6,000,000 dollars a year by not trying to have a sealed system (7). This has four profound impacts.

1. No loss in pavement performance.
2. It makes PCC more competitive.
3. It allows for more highway rehabilitation and construction.
4. It reduces customer inconvenience related to joint resealing.

BREAKING THE CHAIN

There are tremendous savings available to agencies that do not seal joints. In addition, there is a significant reduction in customer inconvenience and an increase in worker and public safety. In 1990 WisDOT broke the chain of acceptance, that is, of accepting a joint sealing policy based upon a faulty assumption. In 1990 WisDOT determined that there was enough data to show the basic assumptions were false. Thus, the DOT determined it would no longer seal or fill joints or cracks in PCC pavements. This policy applies to newly constructed pavements and maintenance activities. Wisconsin does allow sealing of the shoulder joint if maintenance forces deem it advantageous. Contraction joints are sawed as narrow as possible, generally 3 - 6 mm wide.

Wisconsin's research relates to PCC highway pavement slabs on grade, it does not consider: airfields, interior slabs, buildings, etc.

BURDEN OF PROOF

For 50 years WisDOT has investigated joint filling/sealing in urban and rural areas, for various traffic levels and truck loadings, on open and dense graded bases, on sandy to silty-clay soils, with short and long joint spacings, with and without dowels, etc. The results have always shown that filling/sealing does not enhance pavement performance. WisDOT now believes the burden of proof has shifted. The assumption that water and incompressibles must be kept out of joints has been shown to be without merit. Now the burden is on sealing apologists and researchers to prove, through total pavement performance analysis, that sealing PCC joints somehow enhances performance enough to be cost-effective.

The creation of a new super sealant in no way changes the need for more holistic research, as discussed under "Agency Perspective". Until it is proven that PCC pavement joints must be sealed to enhance pavement performance there is no need to consider different sealant systems.

EXPLANATIONS

It appears the old axiom (that water and incompressibles must be kept out of a pavement joint in order to get good pavement performance) is not true. How, then, can the often seen improved (or at least equal) performance due to unsealed joints be explained. Consider several possible explanations.

1. Stress Concentrations.

In the 1960's Wisconsin engineers noted that filled joints did not seal the joint for long, they soon became partially sealed. Even truly sealed joints deteriorate and became partially sealed. It has been postulated that the partially sealed condition allows incompressible material to enter the joint at the discrete locations of sealant failure. When the pavement expands the expansion force is concentrated entirely at the discrete locations of the incompressibles, causing extreme stress concentrations with the associated spalls and corner cracking (crows-foot cracking).

Wisconsin’s unsealed joints are sawed 3 - 6 mm wide, they become uniformly filled full with fine incompressible materia1 (except the top 25 mm or so which is kept clear by traffic). When the pavement expands the stress is uniformly distributed across the entire pavement cross section. This uniform stress can only amount to 7000 - 14,000 kPa maximum, well below the compressive strength of the concrete.

2. Incompressible Locations.

The incompressibles are not near the top of the joint so there is no stress at the top joint edge in hot weather, either due to expansion and/or curling. In addition, no large incompressibles get into the narrow joint to cause stress concentrations.

3. Construction and Maintenance.

The initial joint sawing can cause spalling or induce stresses which lead to spalling.

In order to truly have a sealed system resealing is required. The various operations involved in resealing itself often cause some joint spalling. In addition, resealing can result in sealant getting on the pavement surface which causes a bump and lowers ride quality. Resealing can be aesthetically unpleasing. The wide joint reservoir for sealants causes tire noise and can affect ride.

4. Funneling Water.

Wisconsin’s narrow, unsealed joints are actually quite impermeable in warm weather. The fine incompressibles cause a tight seal (water will stand in a joint long after a rain). In the winter the base is frozen so no water can get into the structure.

A truly sealed system will soon begin to have sealant failures. These failures result in a funneling effect which allows more water to enter the joint than would occur with a narrow, unsealed joint. This funneling action occurs because the joint is widened at the top to make a reservoir and the sealant is generally recessed -- when the sealant fails a natural funnel is created to intercept and direct water into the pavement structure.

WisDOT research clearly shows that the best overall PCC pavement performance is achieved with very narrow, unsealed joints. The next best performance is with sealed joints. The very worst performance results from partially sealed or filled joints. Unfortunately, every sealed joint will decay into a partially sealed joint, unless an incredible resealing regime is followed. Even with such a regime the pavement performance will not equal that of an unsealed system.

CONCLUSIONS

As a result of nearly 50 years of research on PCC pavements in Wisconsin the following is concluded.

1. Research on the need for PCC joint sealants must be kept focused on the customer's needs.
2. The customer's needs relate to Total Pavement Performance (distress, ride, life, materials), convenience and safety. These factors are not positively effected by joint sealing.
3. Joint sealing is not cost-effective for PCC pavements.

RECOMMENDATIONS

1. PCC pavement contraction joints should be left unsealed and sawed as narrow as possible.
2. Highway research must focus and concentrate upon user needs, this means the primary evaluation criteria for joint and sealant studies must be total pavement performance.

NATIONAL CHALLENGE

WisDOT has not moved hastily on this issue. Since 1967 WisDOT has asked for a fair, objective evaluation of PCC joint sealing. Sufficient data has been collected and independently verified to compel a national investigation of this issue. A national technical working group has been assembled to determine whether or not PCC joint sealing enhances pavement performance and if so, whether or not it is cost-effective. A proposal has been made to the National Cooperative Highway Research Program to study the seal - no seal issue. Many agencies and associations are supporting a thorough study, devoid of the constraining assumptions of the past. In fact, the same studies should be expanded to asphaltic pavements.

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FIGURES

Figure 1. PDI Ratings on USH 51 -- Three Independent Teams

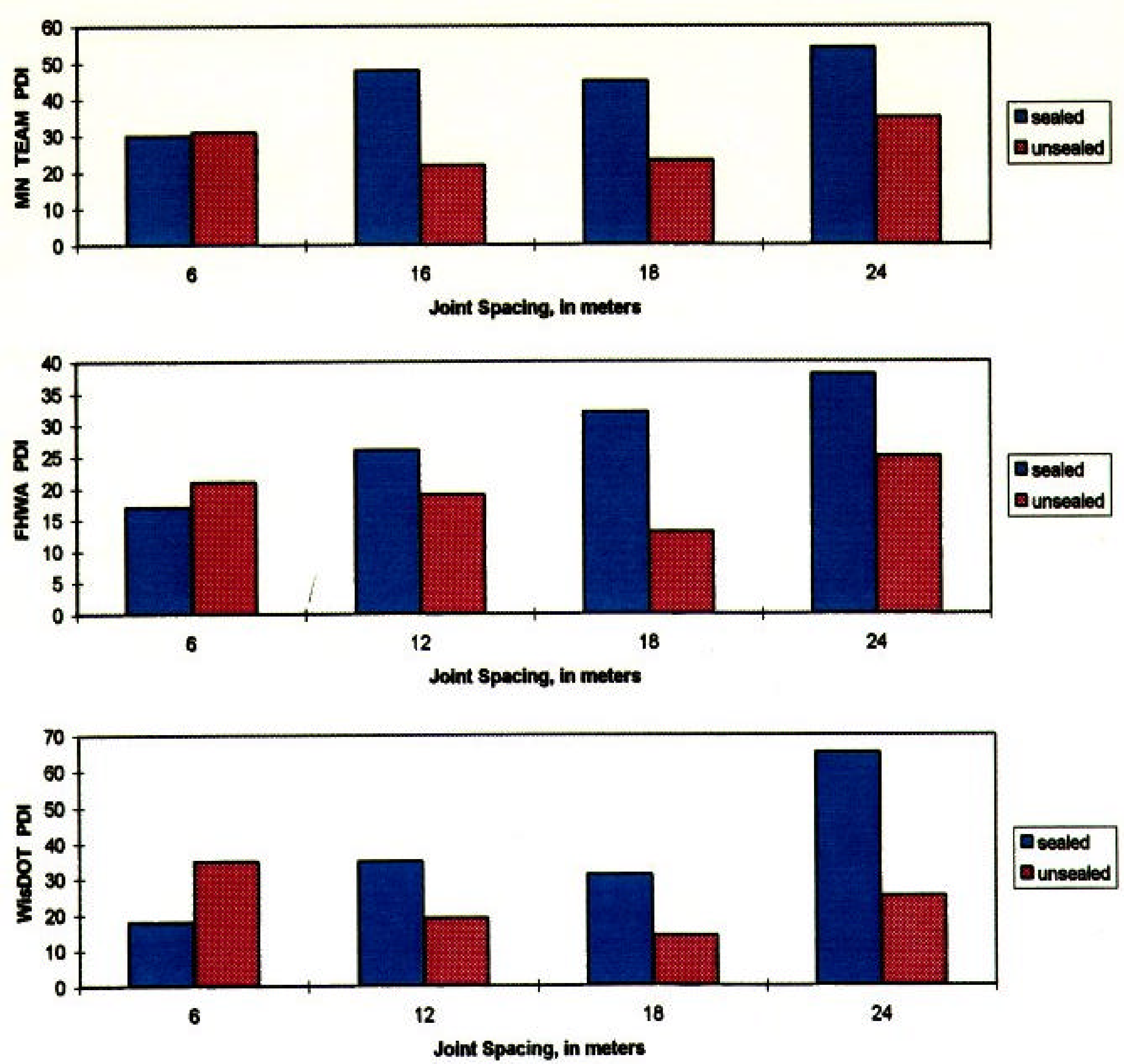


Figure 2. International Roughness Index (IRI) -- Summer

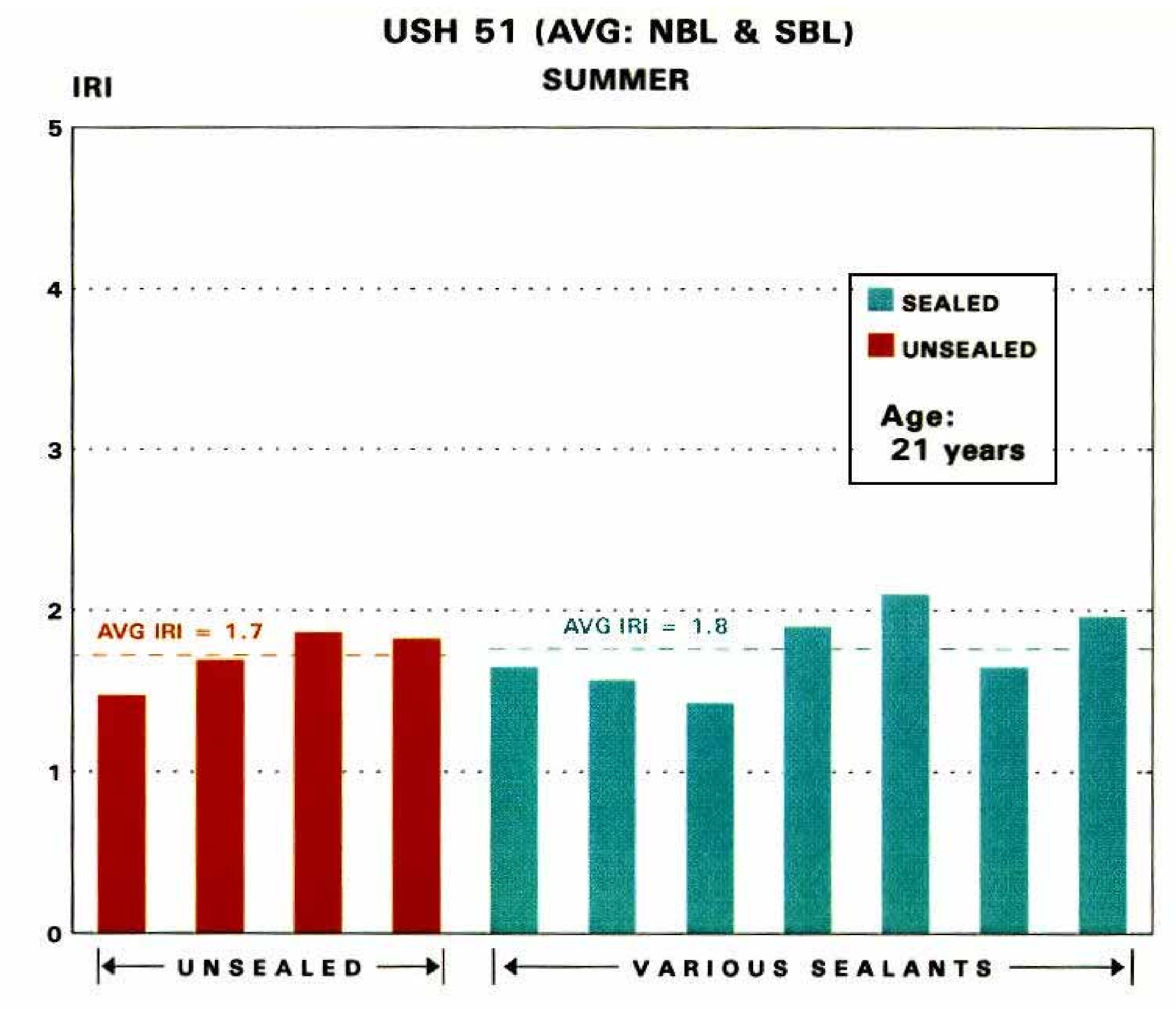
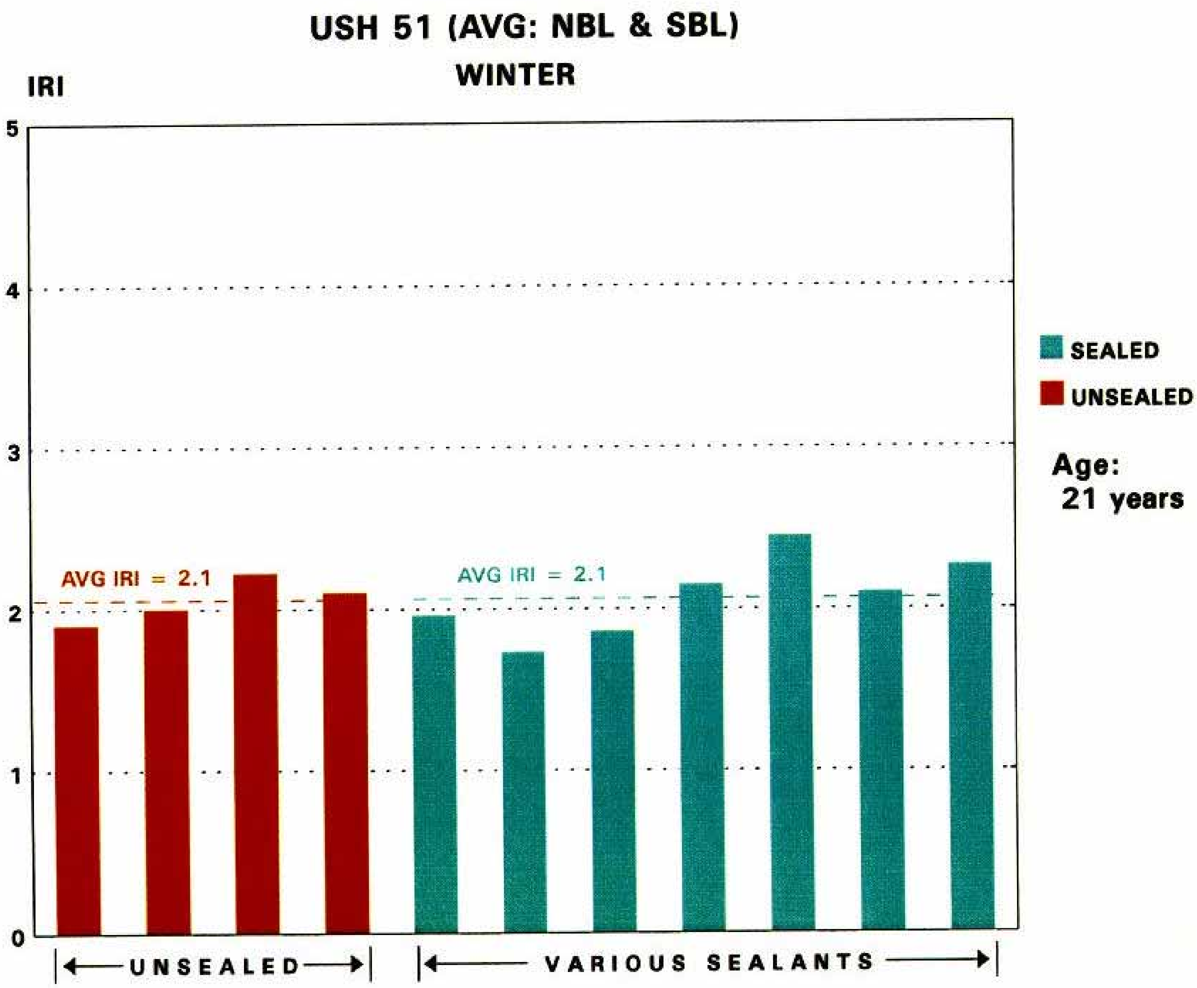


Figure 3. International Roughness Index (IRI) -- Winter



TABLES

TABLE 1. Comparisons of Pavement Distress Indexes (PDI) (Smaller PDI indicates better conditions)

Highway	Test Age	No. of Test Sections	Average PDI	
			Sealed Sections	Unsealed Sections
USH 18/151	12 years	5 Sealed 2 Unsealed	12	11
USH 16/190	12 years	7 Sealed 4 Unsealed	20	17
STH 29	8 years	2 Sealed 2 Unsealed	8	8
STH 164	8 years	3 Sealed 3 Unsealed	11	11
		Weighted Average	15	13

TABLE 2. Comparison of International Roughness Indexes (IRI) (smaller IRI indicates better ride)

Highway	**Test Age**	**No. of Test Sections**	**Average IRI (m/km)**			
			Summer		**Winter**	
			Sealed	**Unsealed**	**Sealed**	**Unsealed**
USH 18/151 **(no dowels)**	10 years	5 Sealed 2 Unsealed	2.01	1.97	2.17	2.01
USH 16 (no dowels)	10 years	4 Sealed 3 Unsealed	2.75	2.75	2.83	2.91
STH 29 **(dowels and no dowels)**	6 years	2 Sealed 2 Unsealed	1.49	1.31	--	--
Weighted Average			2.19	2.12	2.46	2.55

PRINTS

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Print 1. The "poor performing" unsealed test section with six meter joint spacing at 22 years of age. The first half of this test section has no mesh problems and is in nearly perfect condition.

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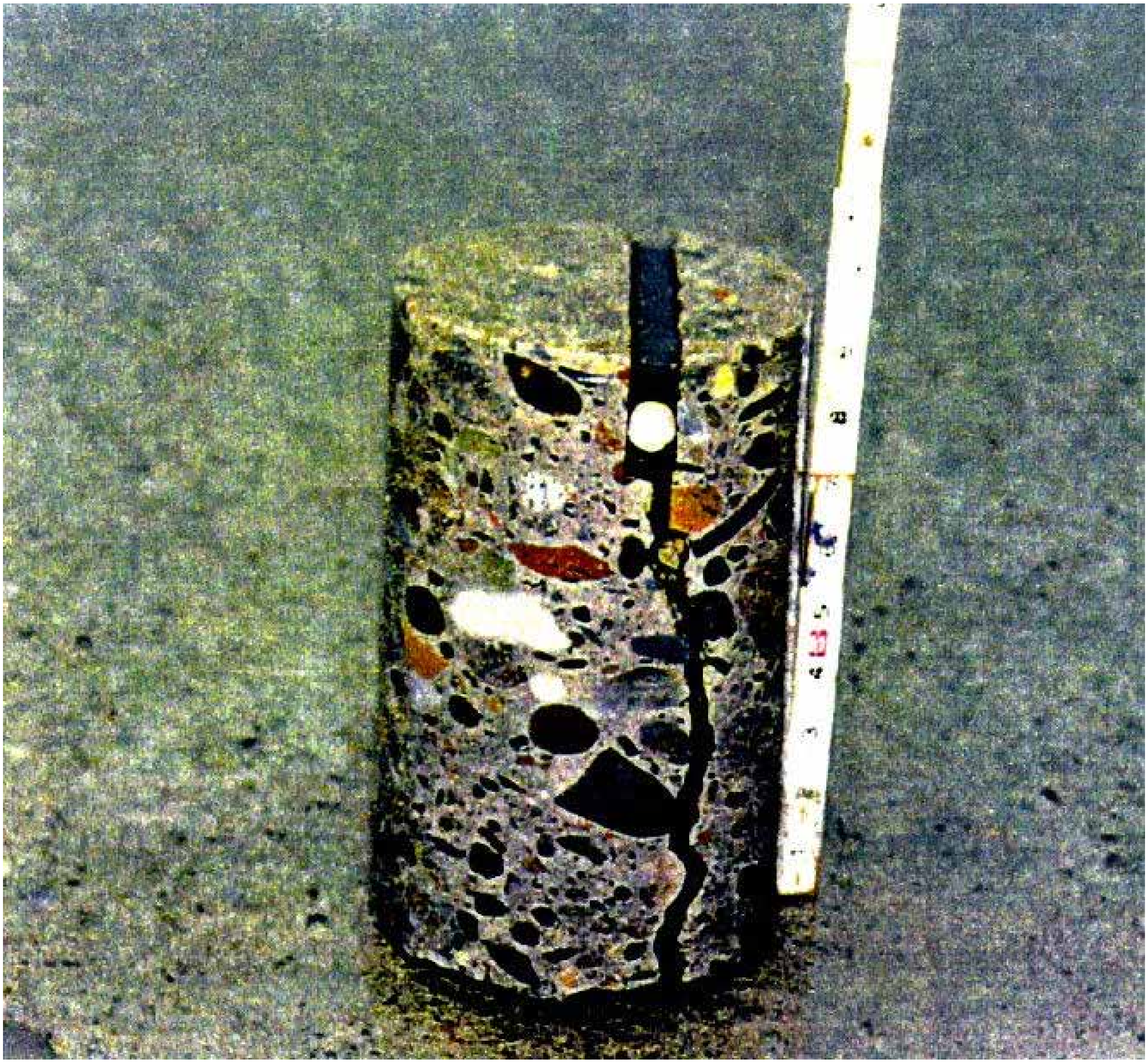
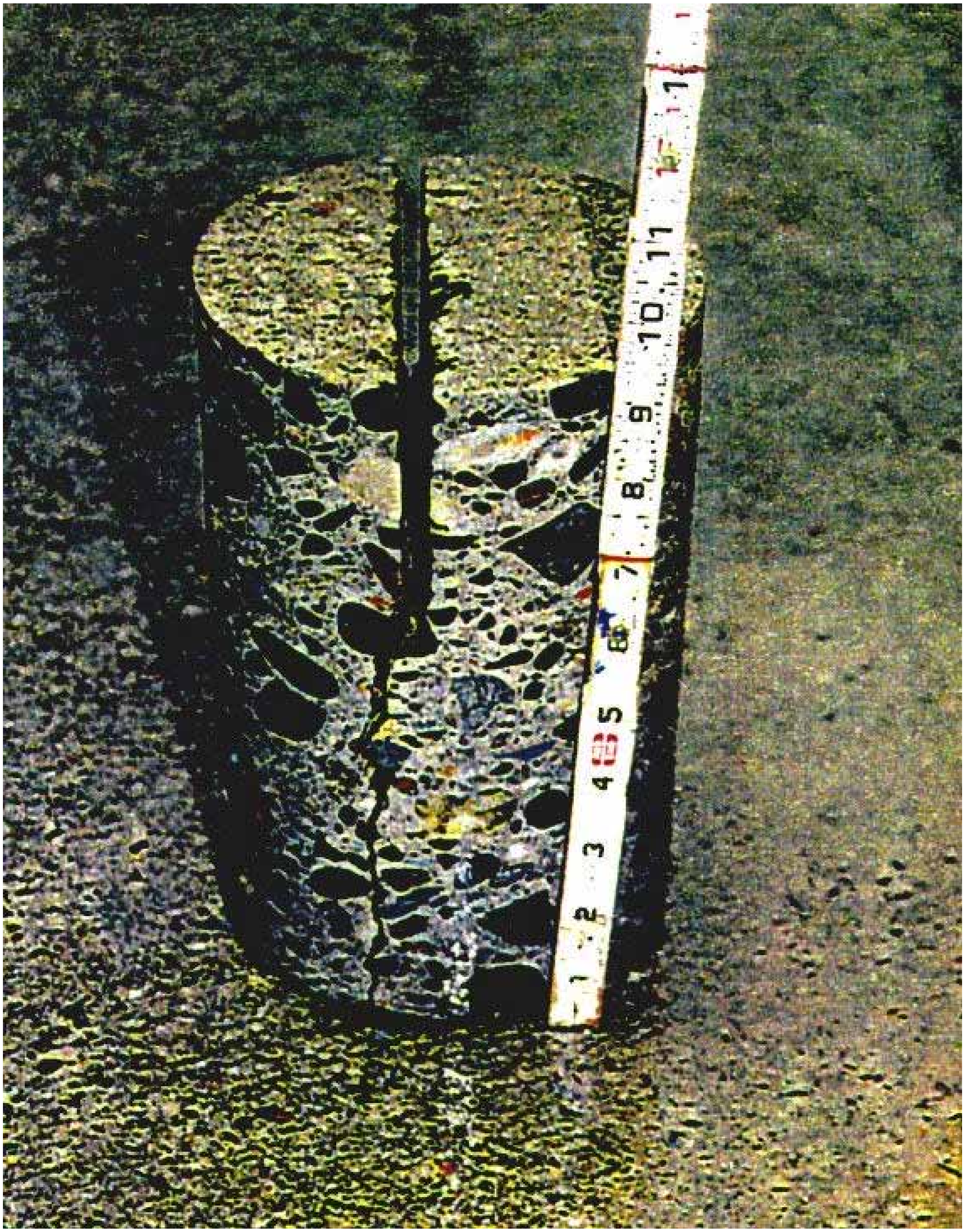
Print 2. Same test section as Print 1 but in the area of worst distress. The mesh problems resulted in several repairs.



Print 3. Core of sealed joint at 21 years of age -- six meter joint spacing. No distress.



Print 4. Core of unsealed joint at 21 years of age -- six meter joint spacing. No distress.

Print 5. Core of original sealed joint at 21 years of age -- 24 meter joint spacing.
Considerable distress. (Core is top side down)

Print 6. Core of unsealed joint at 21 years of age -- 24 meter joint spacing. Considerable distress. Distress is a function of joint spacing not joint sealing. (Core is top side down)