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The invitation to participate your annual meeting was one which gave me a feeling of both honor and pleasure. I am honored to have been asked to be a part of what promises to be an excellent program. I am especially pleased to present some of our experiences and to express a few thought on our mutual problems and successes.

The Division of Highways, engineer for the highway user, is certainly one of the better customers for your products. It is estimated that we annually use some 40 million tons of sand and rock for all uses, and place approximately 3 million yards of concrete. This is an important part of our construction program which adds some 300 miles of new freeways each year to your highway system at a cost of some $450 million. This achievement is only possible with the full cooperation which we highway engineers obtain from you in the construction industry.

In preparing our specifications we have always listened attentively to your representatives. As such I feel our specifications are a tool which provide the taxpayer with a durable structure that can be built in a practical manner. Our specifications are a contractual guide and a pre-bid source of information aimed towards building structures that will last at least 50 years. Specifications in effect are the disciplines of any construction. In highway concrete construction they have special significance. I therefore felt that by a series of slides I would show you why some of our specifications are unique when compared to normal construction.

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THE DISCIPLINES OF CONCRETE

By

J. L. Beaton

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Specifications in effect are the disciplines of any construction. In highway concrete construction they have special significance. I therefore felt that by a series of slides I would show you why some of our specifications are unique when compared to normal construction.

We essentially build two types of structures with concrete - bridges and pavements. We have many other miscellaneous uses for concrete, such as curbs, headwalls, retaining walls, etc., but still most of our thinking is oriented towards the bridge and the pavement. Both of these structures are relatively thin-walled, but in somewhat different environments. The bridge, with the exception of the footings, is entirely surrounded by exterior air, while the pavement is enclosed on three sides, but with its large top surface exposed to the elements; both are exposed to the pounding of traffic. Our specifications reflect these exposures and are designed to provide an overall durability of at least 50 years. This is our aim, but not always our realization.

When compared to this building we are in with its controlled environment, vertical sides and relatively static loads - a bridge or pavement has a real job to perform. Imagine standing like this bridge with your feet in the mud and your bare head subject to wind, sun, ice and snow, and being constantly pounded by a 30 ton behemoth, often with chains for shoes.

In general, our philosophy of control of concrete is to assure ourselves of the quality of the materials entering the mix in advance of their use, and then controlling the mix so as to produce a uniform and consistent product. With the exception

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of prestressed work, and a few special jobs, our only application of post construction strength requirements is to define when the pavement may be opened to traffic, or the forms stripped from a bridge. The high strength requirements of our prestressed work necessitate that this work be controlled by cylinder strength.

So far as curing is concerned, our pavements are cured by the pigmented curing membrane method and our structures by 7-day wet method. Precast work may be cured by the wet method for 7 days, but most fabricators choose to cure by steam. The one exception to this concerns piling which are to be exposed to salt water. In this case, even if steam curing is used, the pile must be kept continuously wet for 7 days.

Cement

Each of the ingredients of our concrete has certain special requirements. We use a modified Type II cement, for instance. Our requirement for low alkali cement stems back many years, to the late thirties and early forties when the causes of some mysterious cracking became better understood. One of my predecessors, Tom Stanton, is credited with some of the first work isolating the cause of such cracking and gel exudation, which we now, of course, recognize as the result of a reaction between some types of aggregate and the alkalies in cements. The obvious solution was to eliminate one or the other. Since reactive aggregates were found to be pretty well scattered throughout the State, it was believed the best control would be

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to limit alkalies in the cements. The cement industry, an ingenious lot, found that alkali in cement would be limited by reasonable means and at comparatively low cost. We believe the procedure has been a complete success. Except for some unusually reactive aggregate in the Bishop area, the low alkali cement has reduced or eliminated this type of deterioration to a tolerable level. We believe there is another worthwhile benefit by the use of low alkali cements in that they seem to have less drying shrinkage than do the high alkali cements. Recently researchers have recognized a similar reactivity labeled "alkali-carbonate reaction." Controlling the alkali content has been found beneficial in these cases too, and the practice of specifying low alkali cements appears to be increasing.

We have not limited the tricalcium silicate of cement for several reasons. (1) We do not have many thick sections which would necessitate limitations on heat development caused by high C_3S content. To be sure, we do think the temperatures of concrete placed at times is too high for best results, but we can live with most of our heat problems if other measures are taken to control the temperature of the mix. (2) C_3S is indirectly controlled by its adverse effects on other properties. For example, it is likely that a cement excessively high in C_3S would not meet our contraction test. (3) C_3S, which is responsible for much of the early strength permits more rapid construction, which can result in earlier form removal, faster placement of the concrete, etc., which in some cases lowers cost.

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After several years of research, we developed the concept of minimizing contraction of cement by adjusting the gypsum content. The effects of gypsum were known for some time, but we were one of the first to take advantage of limiting drying contraction. Lower cement shrinkage means less concrete shrinkage and therefore is desirable.

We found that some of these Type II prestress cements required slightly more gypsum for "optimum" than did the regular Type II, more than permitted by ASTM specifications. Therefore, we have raised the SO_3 limit to permit attaining minimum contraction with this special type cement.

Aggregate

Shrinkage of concrete is generally an undesirable property. At the moment, I am referring to volume changes that occur as a result of moisture movement (not thermal contraction). Concrete certainly would be less troublesome if it were completely passive. While shrinkage and expansion may be impossible to eliminate, there are certain things that can be done to reduce it. We attacked the problem of volume change on a broad front. We have limitations on the amount of active clay or other coatings on aggregate. We have a contraction limit on the cement used in our work, and we restrict the use of some admixtures that are known to increase drying shrinkage of concrete as measured by our test method. There is some feeling that we ought to go further and place a limitation on the shrinkage attributed to the various

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aggregates used. Some other groups have done this, (we have been unjustly accused of this at times) but we feel that most highway structures can be designed and constructed with nearly all available aggregates which will perform adequately without using special aggregates. To be sure, there are some materials used that cause problems, such as curled pavement slabs, excessive cracking of such members as bridge decks, and unpredictable cambers in bridges, but one of our goals, in a broad sense, is to learn through research and experience how to cope with these conditions by means other than arbitrary elimination. Whether or not this will be possible, only time will tell.

Sodium sulfate soundness loss has long been used as an index of aggregate suitability. We neither favor its use, nor do we know what other measure could be used in its place to control some of the poorer aggregate now being eliminated. We would replace it tomorrow (well, maybe Monday). If a suitable replacement were available. Nationwide there is recognition of its limitations, but no offers of what to do about it. Research is being done on a rather broad scale, but results have been frustrating and disappointing.

A freeze-thaw test for concrete aggregate was developed by the Materials and Research Lab on the concepts set forth by Mr. T. C. Powers of the other PCA (Portland Cement Association - not Pacific Cement & Aggregates). In effect, it allows the use of many local aggregates that would not pass the usual ASTM tests. It is the only freeze-thaw test that we are aware of being used

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for acceptance that so fully takes into account the natural environment. Unfortunately the test cannot be accelerated. It takes about four months to complete, including 10 weeks of soaking and freeze-thaw cycles. We have, however, been able to, in most cases, provide test results far enough in advance to avoid delays on the job. At the present time our Lab is the only one in California equipped to perform this test, although there are others in the East.

Aggregate - Grading

We are all aware of the need to control the grading of aggregate in concrete. We believe uniformity of grading from batch to batch is as important, if not more important, than the actual grading. Satisfactory concrete can be made from quite a wide variety of aggregate gradings. Some, of course, will not be efficient in terms of optimizing the use of the cement, some may cause problems in handling, and others may cause difficulty in finishing. Our approach has been to allow the use of as many sources as reasonably possible provided that once a typical grading from that source has been established, it must be maintained within the narrow limits. In other words, while we have given producers a wide choice of gradings, we do not want variations during any concrete production cycle. This sounds unbelievably simple but has proved very troublesome. Unfortunately, there are poor handling practices and inadequate facilities that cause unwanted variations in grading. We recognize there is more than one side to difficulties with meeting grading requirements, and I can assure you we are constantly seeking ways of improving control test procedures.

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We feel that industry could assist in this area by providing safe and adequate sampling facilities where they are not now, installing of baffles in some of the bins to prevent segregation, and better stockpiling and handling procedures to prevent degradation, segregation, and impurities such as clay balls.

Improvement in this area will result in better control of the consistency of the mixed concrete which reduces or eliminates problems on operations that follow. While we believe finish screening would provide improved grading control and encourage it, we know that uniform concrete can be produced by the more conventional procedures with a little care.

Quality Control

We believe quality control is the responsibility of the concrete producers. Many producers now have very good effective quality control units within their organization. We feel that a review would reveal that these operations actually save money rather than cost money even if only direct costs were considered. They often do a good deal more. They often prevent dissatisfied customers, prevent law suits, and build good will. It puts everyone on a more even basis for bidding, and helps many to recognize for the first time the inherent variability of a product that is unique in its manufacture, and points out some obvious deficiencies in specifications for this product. Statistical quality control of our work is becoming more widespread as we become more familiar with its use. We have introduced statistical type specifications into a few jobs of our own and

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found that while there are limitations, there are a lot of worthwhile applications.

I am sure the use of this tool to control concrete construction will increase and, combined with effective automatic controls, will relieve the engineer of much of the tedium of inspection.

Strength

Unfortunately, the better materials from the volume change standpoint are becoming scarcer or harder to get, while designs are leaning toward the type of structures that are more sensitive to materials properties. Spans are getting longer, required strengths are going higher, and we are demanding more and more in the way of performance. What this all adds up to is that your jobs are becoming more and more exacting and difficult. Quality control takes on a new meaning when the design calls for a strength near the maximum possible with a given set of materials rather than half of what's attainable. Like it or not, it means a tightening of construction practices that have in the past been of lesser importance.

Placement

The high speed placement of concrete is a two-edged sword - When something goes wrong it's a real mess, but in general the buyer benefits because this requires high quality, uniform material. Now that the pumpcrete industry is getting away from over-sanded mixes, we are starting to use it more. One problem

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we have recently encountered is the fact that aluminum pipe cannot be used due to the adverse effect of the worn-off aluminum in the concrete. The slipform paver is giving us the best concrete we have ever had - that is below the top 3/16 inch. Unfortunately, finishing is our worst problem, and this is the part of the pavement that works the hardest.

Finishing

Here are two examples of surface deterioration, both in less than 5 years. The first is straight forward rubber tire wear - not only is this concrete pavement rutted, but the skid resistance is lowered below the point of safety. Here the pavement is rutted by chain wear.

Finishing practices that require excessive water and working can cause weak mortar topping and will result in rapid wear. We are doing a great deal of work in the texturing field, especially to develop a durable non-skid surface. You are probably also aware that the industry is developing mechanical devices to provide better finishing.

All these operations have a profound influence on the final result, and yet being very much an art, cannot be fully controlled by specifications. Artisans are disappearing. It is now common to find finishers and others responsible for these operations who are not only unaware of good concrete practice, but also have no interest beyond getting the job done. It appears to me that this is an area where we could use some well organized

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training. Education and supervision of inspectors and workmen alike are necessary if good practices are to be followed. We can hardly blame one for not using them if he doesn't know what they are - we can only blame ourselves, for this knowledge is not inborn. We realize that a building job is more successful if it makes a fair profit. To make a profit, the job must be done within the time limitations set. Speed is of the essence. We point with pride at a pavement job that placed 7000 yards in a day, and a bridge at 1800. This means there is less time for batching, less time for mixing, less time for loading and unloading, less time for attention to details such as cleanliness of trucks, wear on mixer blades, scale adjustments, and control tests. We think plants and plant operations could be improved by more automated interlocking controls that work, better designed weighing systems that take advantage of modern electronic devices, better, faster tests that tell us about the composition and potential quality of the mixed concrete before it hardens.

Curing, like this subject today, comes at the tail end of the operation. This should be the most disciplined of all operations, but unfortunately at this point, everyone feels relieved - the main event has taken place, it's time to go home. As a result, this important operation is too often neglected. Its importance is often not appreciated. To us, it doesn't make sense to go to all the trouble of obtaining Type II, low alkali cement with special requirements, clean, sound, well-graded aggregates, going through intricate procedures to see that it is

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accurately proportioned and well-mixed, placed and finished, then neglect the very operation that can affect its strength up to 30% or more. We have been making curing studies of one kind or another for many years. Each one has demonstrated the importance of curing - higher strengths, greater abrasion resistance, better corrosion resistance, less cracking, etc. We are gradually upgrading curing materials and practices designed to improve the curing operation. We need cooperation from those responsible for construction in raising this aspect of concreting to the level it deserves.

In closing, I might say a few things about new developments or trends. We are moving more and more toward design of concrete and special properties of the materials that fit the environment. Demands on concrete are reaching and sometimes exceeding its limitations. Modifications are being made to meet these demands, and in some cases, new or supplementary materials are being sought. We expect greater use of special cements, coatings, admixtures such as polymers, and fibers. Creep and shrinkage of normal concrete may not be as closely controlled as necessary when considering the long thin bridge spans on the drawing board. We have faith in the ability of your industry to meet these challenges and will find a way to supply the kind of concrete needed for our California highways.

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