Summarized Committee Report 1948-1960: Salvaging Old Pavements by Resurfacing

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Rçcognizing that the salvage of old pavements was a national problem, the Highway Research Board, through its Department of Maintenance, organized a committee in 1948 to assemble and disseminate information relative to prevailing practices to those agencies concerned with such work.

The first phase of committee study was to assemble information regarding practices in design and construction currently in vogue from 1948 through 1951, and was terminated with the publication of HRB Bulletin 47.

The scope of committee activity was then expanded to keep abreast of new developments in practices, methods and technique in the salvage of both rigid- and flexible-type pavements. To this end, the committee has encouraged the presentation of papers covering experimental work and new methods and means to improve the performance of salvaged pavements, and has published replies to questionnaires dealing with specific aspects of such work.

This paper covers briefly what are considered to be the most significant studies and experimental work, completed or in progress by research agencies of highway departments and educational institutions, as reported to the Highway Research Board.

BY 1947 it was recognized that the salvage of old pavements was a national problem, d in January 1948 the Highway Research Board took action to assemble and dissemin- information relative to prevailing practices to those agencies and individuals con- rned with such work.

A committee was organized under the Highway Research Board, Department of intenance, to "provide information that may be used by cities, counties, states or ividuals in the salvage of old pavements by application of a resurfacing treatment." e committee was designated "Project Committee No. 4, Salvaging Old Pavements by surfacing."

During the period from January 1948 to January 1952, the committee functioned un- the chairmanship of Robert H. Tittle, Engineer of Construction, Illinois Division Highways. Committee membership included individuals from the Portland Cement sociation, the Asphalt Institute, the petroleum industries, educational institutions highway departments.

The author of this paper was not a member of the committee during this period and ailed activities are not available to him. However, it is known that a survey was ducted to assemble information as to current practices in pavement salvage during t period.

Activities of the original committee were concluded with the publication of HRB letin 47 and the committee was inactivated in January 1952. Bulletin 47 contained information assembled by the committee relative to (1) economics of resurfacing, (2) study of existing pavements both portland cement and bituminous types, (3) surveys and plans, (4) preparation of the old pavement for resurfacing, (5) widening pavements and (6) resurfacing with both rigid and flexible-type overlays.

The committee was reactivated in January 1953 to study the performance of pavements after salvaging. Reorganization of the committee was essential due to the resignation of Mr. Tittle as chairman and a few changes in membership. The author of this paper was named to succeed Mr. Tittle, and the purpose of the committee and its scope of activities were revised to read:

Purpose. "...To study the performance of salvaged pavements to provide more comprehensive and instructive information as to methods of salvage, design and construction."

Scope. "1. Study of new developments in pavement salvage.
2. Evaluation studies:
   a. Pavement salvage by resurfacing and for which evaluation data are available from a survey.
   b. Underseals or other means of restoration of subgrade support for rigid-type pavements in connection with resurfacing.
3. Study of test methods and technique to determine additional strength provided by various thicknesses of resurfacing."

It may be well to state specifically relative to committee activity—its function is not to conduct research or experimental work but to assemble and analyze information and data from any agency performing such work, and disseminate worthwhile findings by committee prepared or sponsored publications.

As a means of gathering information for analysis and/or dissemination with minimum delay, the committee seeks out and encourages prospective authors concerned with some phase of research or experimentation within the scope of committee activity to present papers covering such work under committee sponsorship. So far as the committee may have knowledge, authors are selected to assure nationwide coverage and will be from highway departments, educational institutions and engineering, industrial and governmental agencies performing or concerned with pavement salvage.

For convenience in this paper, the writer will arbitrarily classify the subject matter of committee sponsored papers, or replies to questionnaires mentioned herein, under one of the three items set forth above as scope of committee activity.

DISCUSSION

A summary of pertinent information given in committee prepared or sponsored publications, and classified herein as applicable to one of the items previously mentioned as scope of committee activity, follows.

A. New Developments

1. Studies of Reflection Cracking in Flexible-Type Overlays

a. Personnel of the Joint Highway Research Project, Massachusetts Institute of Technology and Massachusetts Department of Public Works. This agency has made an intensive study of means and/or methods of preventing or controlling reflection cracking in flexible-type overlays on rigid-type pavement. The titles of committee sponsored papers presented by it are:

(1) "Control of Reflection Cracking in Bituminous Resurfacing Over Old Cement Concrete Pavements." The paper described several methods of experimental joint treatment and reinforcing for the years 1952 and 1953, and was reported in 1954. The devices used included plugging joints with cement grout or a stabilized soil mix, breaking bond between the bituminous concrete and cement concrete at joints, placing

metal plates on concrete, and reinforcing bituminous concrete with various types of metal either on the old pavement or between binder and surface courses of the overlay. Partial conclusions from this study are stated to be:

(a) Reflection cracking results from differential vertical or horizontal movement in the underlying concrete. Vertical movement can usually be controlled by adequate subgrade support, but horizontal movements due to temperature changes are inevitable and are a primary cause of reflection cracking, particularly over transverse joints.

(b) Tests described do not establish any sure method of eliminating reflection cracking though there are indications that its extent can be reduced.

(2) "Current Practices and Research on Controlling Reflection Cracking." The paper presented in 1955 reviews methods proposed for controlling reflection cracking and classifies them as (a) prevention and (b) sealing. The methods described and commented on include (a) elimination of joint movement by filling the joints with incompressible material, (b) breaking the pavement into small pieces before resurfacing, (c) increasing the thickness of overlay, (d) use of additive to the bituminous mix to increase ductility, (e) use of mesh reinforcing in overlay over existing joints, (f) use of light metal plates over the joints and under the overlay, (g) use of a granular intermediate course, (h) sawing grooves in the overlay over the joints in the existing pavement, (i) use of burlap layers in the bituminous mix over the existing joints, and (j) sealing methods and materials as maintenance measures for reflection cracks. The paper concludes that no wholly satisfactory method or technique for crack control has been developed. Recommendations relative to further studies are made.

(3) "Progress of Reflection Cracking in Bituminous Concrete Resurfacing." The paper covers a study of reflection cracking in overlays on rigid-type pavements in Massachusetts with standard Class I state specification bituminous mixes and also mixes modified by various types of rubber additives. The study was started in 1952 and reported in 1956. Surveys have been conducted on twenty-five 1,000-ft sections of the pavement to evaluate their relative performance. From the study it is concluded that about 90 percent of the possible potential reflection cracking will take place by the time five or six years have elapsed regardless of the addition of additives.

b. Personnel of the California Division of Highways. Paper by Ernest Zube titled "Wire Mesh Reinforcement in Bituminous Resurfacing," describes an experimental project in which the California Division of Highways in 1954 placed several test sections for the purpose of comparing the relative merits of various types of wire mesh as a preventative for reflection cracking of bituminous overlays. A cost analysis is made and a summary and partial conclusions are given. The cost analysis, in part, states that for continuous reinforcement the cost is equal to 1½ in. of bituminous resurfacing. Limited service prevents definite opinions regarding the effectiveness of the various types of wire mesh used in preventing or retarding reflection cracking. It is stated, however, that there is definite evidence that the wire reinforcement has prevented the formation of longitudinal cracks.

c. Personnel of the Iowa State Highway Commission. Paper by Stephen Roberts titled "Cracks in Asphalt Resurfacing Affected by Cracks in Rigid Bases," describes several test sections established in 1948 and 1949. The methods used include cleaning cracks and filling with binder mix and/or binder mortar containing finer aggregate only, the use of SC-5 cutback asphalt as a first course of the overlay with an additional 3 in. of asphalt concrete placed in two courses using asphalt cement, and the use of 100+ penetration asphalt cement for the surface course versus 70-85 penetration grade for other sections. Based on observations made during the investigation, the summary states in part:

(1) Where base cracks were cleaned and refilled before resurfacing, results indicate that an asphalt mortar is superior as a crack filler versus the regular binder coarse mix; where cracks were not cleaned or refilled an additional 1½ in. of overlay did not significantly reduce reflection cracking.

(2) Some indications were noted that reflection cracking was affected by the penetration grade of asphalt used in the overlay.

d. Personnel Anonymous. HRB Circular 413, "Summary of Replies to Committed Questionnaire." The circular (in part) summarizes replies to a question asked in a questionnaire to all highway departments in 1958 relative to methods used or under test as a preventative for reflection crackin[g]. Replies indicate that numerous methods have been or are being used, but perhaps the use of wire mesh and/or granular intermediate courses may b[e] considered as most extensively used.

2. Studies and Experimental Work With Rigid-Type Overlays

a. Personnel of the Portland Cement Association. Paper by Earl J. Felt titled "Resurfacing and Patching Concrete Pavements With Bonded Concrete," covers laboratory bond tests, experimental field projects, a survey of projects in use and recommended practices. A description of five experimental pilot study projects build from 1951 to 1954 is given—overlays varying in thickness from ¼ to 6 in. Field projects in Michigan, Nebraska, New York, Ohio, Pennsylvania, Rhode Island and Wisconsin are described. The paper sets forth the following pertinent findings: Laboratory data and field work indicate that bond strengths as determined by shear test may frequently be 400 lb or more, but that strengths of 200 lb per sq in. or even less may be adequate. The two ma[in] factors governing bonding are (1) the strength and integrity of the old bas[e] concrete and (2) the cleanliness of the old surface. Best bond was obtain[ed] when the base concrete was dry and grouted. Good compaction of the fre[sh] concrete is also required for a strong bond. The performance of experimental projects and other projects in service shows that properly bonded surfaces will withstand extreme climate conditions and heavy traffic. Th[e] bonded surfaces giving satisfactory service date back to 1913.

b. Jointly by Personnel of the Iowa State Highway Commission and the Portl[and] Cement Association. Paper by J.W. Johnson and W.G. Bester titled "Widening and Resurfacing Highways With Concrete," describes resurfacing rigid-type pavements in Iowa with rigid-type overlays and includes a number of projects over a number of years. The work is arbitr[ari]ly divided into five-year periods from 1930 through 1950 for the purpose [of] design comparison and in order not to go into unnecessary detail for each project. Performance data are given for each five-year period.

The paper also covers a research project in 1954 in which the old pavement was widened 2 ft on each side with 10 in. of concrete. Resurfa[cing] was 1, 2 and 3 in. in nominal thickness, bonded to a structurally sound c[on]crete pavement. Reinforcement was used in some sections and not in ot[her] sections. In general, the condition of the pavement at time of reporting was good.

The paper concludes in part: It does not appear that bonding or no bo[nding] of the overlay to the old pavement was of importance in performance for thicknesses of resurfacing from 4 to 6 in. This paper is considered applicable also to "B—Evaluation Studies."

c. Personnel of the Washington Highway Commission. Paper titled "Preparing Old Pavements for Resurfacing With 50-Ton Compactor," by John L. Stackhouse, describes in detail the use of a 50-ton pneumatic-tired roller in seating an old portland cement pavement preparatory to widening and resurfacing in 1956. After using the roller a crushed stone base course of 3-in. minimum thickness was placed over the widened pavement followed by a top course of like material 2 in. in thickness. A 3-in. flexible-type overlay was then placed over the granular intermediate course.

The paper states that the advantage of the heavy compactor appears to be that by using a weight heavier than legal loads, the weak areas are disclosed and corrections for unstable material in such areas can be made. The paper further states that no reflection cracking has been noted after 18 months, but that main credit for elimination of reflection cracking probably should be given to the granular intermediate course rather than the heavy compactor.

B. Evaluation Studies

1. Pavement Salvage by Resurfacing

a. Personnel of the Missouri Highway Department. Paper titled "An Investigation of Concrete Resurfacing of a Concrete Pavement in Various Stages of Deterioration," by Messrs, Gotham and Lord, deals with two experimental concrete resurfacing projects on US 40 at specified locations in Missouri—one in 1932 and the other in 1936. The 1932 project included two ¼-mi long sections, one with a 4-in. and the other a 6-in. overlay. The 1936 project was 11¾ mi in length and included overlays 4, 5 and 6 in. in thickness. The report covers a study of the effect of thickness on concrete overlay performance, effects of cracks in the old pavement, effects of expansion joints, etc.

In summary, the paper notes some 27 specific findings but only a few considered of particular significance are mentioned, as follows:

(1) A thickness of 6 in. was more durable and theoretically more economical than 5 or 4 in.

(2) The 6-in. surface built in 1932 gave excellent service for 18½ yr and when again resurfaced in 1951 apparently could still have been used for many years without excessive maintenance.

(3) The 4- and 5-in. resurfaces built in 1936 on old pavement in relatively good and in intermediate condition showed considerable distress after 15 yr of service and these, especially the 4 in., would have required extensive maintenance for further service.

(4) ....Considering only those resurfacing slabs which lay on uncracked old pavement, a tendency was noted for such slabs to crack in lengths averaging 20 to 25 ft regardless of the thickness of the resurfacing.

(5) Surface deterioration developed to some degree in each of the various surfaces, but in general the percentage of area affected varied inversely with the thickness of resurface. This paper is considered applicable also to "A—New Developments."

b. Personnel of the Portland Cement Association. Paper Titled "Bonded Resurfacing and Repairs of Concrete Pavement," by William G. Westall, discusses bonded concrete construction and its various applications to a pavement, and describes projects which have been accomplished at air bases from 1955 to 1959; it also illustrates the essential steps in surface preparation and construction. The paper is in two parts—Part I covers thin bonded concrete and Part II deals with bonded concrete for patching and repairing concrete.

Part I describes rigid-type overlays on rigid-type pavements for five airports. The overlays varied in thickness from 1 in. to 4 in. and all were placed under contract conditions.

Part II describes patching and repair of one air force base project with bonded concrete and includes a variety of types of repairs. Conclusions given in the paper are briefly stated herein as follows:

(1) Resurfacing or patching of concrete pavements with bonded concrete ha been proved feasible in both laboratory investigations and field constru tion projects.
(2) When the overlay is to smooth a rough existing surface, a thin surfaci layer will perform as well as, and in many cases, better than a thicke slab, provided adequate bond is obtained between the old and new concrete.
(3) The satisfactory performance of resurfacing or patching with bonded concrete depends on the securing of adequate and uniform bond betwee the two surfaces.

2. Restoration of Subgrade Support for Rigid-Type Pavements in Connection Wit Resurfacing

a. Personnel Anonymous. HRB Circular 413, "Summary of Replies to Committee Questionnaire." The Circular (in part) summarizes replies to a nationwide questionnaire to highway departments, prepared and mailed jointly by the committee and the Highway Research Board in 1958, reques information as to the method of subgrade restoration for rigid-type pavements used preparatory to resurfacing. Replies were received from all b three highway departments. Although numerous methods were mentioned, replies indicated that perhaps bituminous underseals and mud jacking may be considered as most extensively used. To what extent methods used we considered successful is not stated in replies to the questionnaire.

C. Test Methods and Technique to Determine Required Thickness of Overlays

1. General

Information available to the committee indicated that the thickness of ove lays used, regardless of type, was determined by engineering judgment and observing the condition of the existing pavement. Considering that perhaps scientific methods were being used or developed to determine the thickness of overlays required as the tempo of pavement salvage work increased, the committee jointly with the Highway Research Board prepared and sent out tw questionnaires to determine definitely if scientific methods were being used tested.

a. Personnel Anonymous. HRB Circular 316, "Summary of Replies to Com mittee Questionnaire." The summary mentioned above refers to replies a questionnaire sent to all highway departments, territories and cities wi a population of 500,000 or more, in 1954 requesting information as to whether scientific methods were used in determining the thickness of ove lay required and, if so, what methods were used. From replies receive it was shown that no city contacted uses such methods. A few state high departments indicated the use of Hveem Stabilometer, CBR curves or th triaxial test for flexible-type pavements, and some other states stated that some scientific method was being considered or studied. It did not appear that any state was using a scientific method for determining the thickness of rigid-type overlay required. It was contemplated that the committee should maintain contact with highway departments using scien methods to ascertain whether such methods were considered suitable.

b. Personnel Anonymous. HRB Correlation Circular 413, "Summary of Re to Committee Questionnaire." The summary of replies mentioned in thi case refers to a follow-up questionnaire concerning evaluation methods and sent to all highway departments in 1958. Replies did not indicate any change in status regarding the use of scientific methods for determining the thickness of rigid-type overlays.

c. Personnel of North Carolina State Highway Commission. Paper titled "Flexible Pavement Deflection Study in North Carolina," by L.D. Hicks, covers a three-year deflection study of flexible pavements with Benkelman Deflection Gage from 1957 to 1959. Some of the deflection surveys were made before and some after the flexible-type overlays were placed. Pavement design data, subgrade classification and specifications for base and surface courses, together with volume and character of traffic, are also given. An analysis of deflection data is made and from this analysis and the pavement condition, conclusions are drawn and recommendations for improvement in pavement design and construction can be made. The author states in his opinion:

(1) A deflection survey is an excellent means of pavement evaluation.
(2) The determination of maximum deflection, a bituminous plant mix pavement, can sustain without excessive cracking is a complex problem that will require much investigation—in North Carolina the desirable limit has been tentatively set at 0.3 in.
(3) Excessive deflection of flexible-type pavements must be controlled in the preparation of the subgrade—test rolling is an excellent method for locating faulty subgrade.

This paper is considered applicable also to "B—Evaluation Studies."

CONCLUSIONS

Considering the three principal items under "scope of committee activity" discussed rein it may be concluded that:

1. It is probable that some new developments in pavement salvage which would be of neral interest have not come to the attention of committee members and have not en publicized.

2. Information available to the committee seems to indicate that evaluation studies flexible-type overlay performance are indeed limited.

3. Little, if any, progress is indicated by highway departments in the development scientific means to evaluate the additional strength provided by various thicknesses rigid-type overlays, but a few scientific methods being tested for evaluation of xible-type overlays show promise. A written discussion to follow this paper will line scientific methods developed by the Portland Cement Association and Corps Engineers.

4. Practical and effective methods and/or means to eliminate reflection cracking flexible-type overlays will apparently require further study even though quite exsive investigations have been reported.

5. Reflection cracking for rigid-type overlays, regardless of thickness, may not a problem since no studies of this nature have been reported to the committee. The itten discussion mentioned in Paragraph 3 above will mention effective methods to minate or reduce such cracking.

SUGGESTIONS FOR FUTURE COMMITTEE STUDY

1. Determine if reflection cracking of rigid-type overlays is a problem requiring ther study and, if so, what studies should be or are being made in connection with problem.

2. Keep abreast of new developments in design experimental work or construction nique for both flexible- and rigid-type overlays.

3. It is considered that reports of performance of pavements salvaged by resuring are of prime importance. It is of record that many variables have entered into

design for widening and resurfacing for both flexible- and rigid-type bases and overlays. Many miles of pavement have been salvaged and under traffic for some time. Performance reports are pertinent to committee activity and such reports are lacking for projects employing flexible-type overlays and the rigid, thin, bonded type.

4. Contact with states using or developing scientific methods for determination of overlay thickness for either the rigid- or flexible-type should be maintained.

GENERAL COMMENTS

In closing it may be well to advise that publications mentioned for one item under "scope of committee activity" often includes information pertinent to another item.

Titles and authors of committee prepared or sponsored publications for the period 1952-1960, including those mentioned herein, will be found in the Appendix. Several excellent papers not specifically mentioned in the body of this paper appear in the Appendix.

Appendix

HIGHWAY RESEARCH BOARD PUBLICATIONS (1952-1960) PREPARED OR SPONSORED BY HIGHWAY RESEARCH BOARD, MAINTENANCE DEPARTMENT, COMMITTEE ON SALVAGING OLD PAVEMENTS BY RESURFACING

Highway Research Board Proceedings:

1. "Control of Reflection Cracking in Bituminous Resurfacing Over Old Cement Concrete Pavements," by Alexander J. Bone, Lewis W. Crump and Vincent J. Roggeveen. Vol. 33, pp. 345-354, 1954.
Concerns experimental work conducted by Massachusetts Institute of Technology and Massachusetts Department of Public Works. Causes of reflection cracking and several experimental techniques for control are discussed.

2. "Cracks in Asphalt Resurfacing Affected by Cracks in Rigid Bases," by Stephen E. Roberts, Iowa State Highway Commission. Vol. 33, pp. 341-345, 1954.
Covers investigation of reflection cracks in asphaltic surfaces over old concrete pavements. Test sections were established to provide information concerning the growth of reflection cracks.

3. "Widening and Resurfacing Highways With Concrete," by James W. Johnson, Iowa State Highway Commission, and W.C. Bester, Portland Cement Association. Vol. 34, pp. 434-452, 1955.
Covers widening and resurfacing on 45 projects.

4. "Resurfacing and Patching Concrete Pavements With Bonded Concrete," by Earl J. Felt, Portland Cement Association. Vol. 35, pp. 444-469, 1956.

5. "Preparing Old Pavements for Resurfacing With 50-Ton Compactor," by J.L. Stackhouse, Washington State Highway Commission. Vol. 38, pp. 464-471, 1959.

6. "Investigation of Longitudinal Cracking Reflected Through Asphaltic Concrete Resurfacing," by John E. Boring and Bert Myers, Iowa State Highway Commission. Vol. 38, pp. 472-479, 1959.

Medium of Publication Unknown:

(Papers presented January 1960.)

1. "Flexible Pavement Deflection Study in North Carolina," by L.D. Hicks, State Highway Commission.
Covers three-year study to determine maximum safe deflection a flexible-type pavement can undergo in service as measured by Bendelman Deflection Gage.

2. "Bonded Resurfacing and Repairs of Concrete Pavement," by William G. Westall, 'ortland Cement Association.

A discussion of bonded concrete construction and its various applications to pave- ıents, in two parts. Part I covers thin bonded concrete overlays, and Part II deals ith bonded concrete for patching and repairing concrete.

ighway Research Board Bulletins:

1. "Salvaging Old Pavements by Resurfacing," by Robert H. Tittle, Engineer of onstruction, Illinois Division of Highways, and Chairman of Project Committee No. , Bulletin 47, 43 pp., 1952.

2. "Concrete Resurfacing of Concrete Pavement in Various Stages of Disintegration," y D.E. Gotham and G.W. Lord, Missouri State Highway Department. Bulletin 87, 9 pp., 1952.

Covers a study of the effect of thickness on concrete overlay performance, effect f cracks in the old pavement, effect of expansion joints, etc., on two experimental esurfacing projects in Missouri.

3. "Current Practices and Research on Controlling Reflection Cracking," by lexander J. Bone and Lewis W. Crump, Joint Highway Research Project, Massachu- etts Institute of Technology. Bulletin 123, pp. 33-39, 1956.

Reviews and discusses prevention and sealing of cracks as methods to control re- ection cracking.

4. "Condition Surveys of Bituminous Resurfacing Over Concrete Pavements," by ewis W. Crump and Alexander J. Bone, Joint Highway Research Project, Massachu- etts Institute of Technology. Bulletin 123, pp. 19-32, 1956.

Describes a technique for making and analyzing condition surveys of flexible over- ys on concrete pavements.

5. "Pavement Widening and Resurfacing in Idaho," by L. F. Erickson and Philip Marsh, Idaho Department of Highways. Bulletin 131, pp. 19-25, 1956.

Describes the manner and method in which structurally inadequate and narrow ghways were reconstructed to desired standards in Idaho.

6. "Highway Rehabilitation by Resurfacing," by K.B. Hirashima, Territorial ghway Department, Honolulu, Hawaii. Bulletin 131, pp. 26-30, 1956.

Covers rehabilitation of old pavements by resurfacing in the City and County of nolulu.

7. "Conditioning an Existing Concrete Pavement for Bituminous Resurfacing," by ed W. Kimble, Ohio Department of Highways. Bulletin 123, pp. 11-18, 1956.

Describes method of conditioning an unreinforced concrete pavement constructed in rtime for a flexible-type overlay.

8. "Progress of Reflection Cracking in Bituminous Concrete Resurfacings," by ıcent J. Roggeveen and Egons Tons, Joint Highway Research Project, Massachusetts titute of Technology. Bulletin 131, pp. 31-46, 1956.

Covers condition surveys of 25 sections of pavement resurfaced during 1949-1952 Massachusetts.

9. "Rejuvenating Highway Pavement," by John L. Stackhouse, Washington State hway Commission. Bulletin 123, pp. 1-10, 1956.

Describes the resurfacing with a flexible-type overlay of a section of State Highway ear Tacoma, Washington.

10. "Wire Mesh Reinforcement in Bituminous Resurfacing," by Ernest Zube, Cali- ıia Division of Highways. Bulletin 131, pp. 1-18, 1956.

Describes an experimental project in California covering eight test sections with ious types of wire mesh in a flexible-type overlay.

Highway Research Board Correlation Service Circulars:

1. "Salvaging Old Pavements by Resurfacing—Summary of Replies to Committee Questionnaire." Anonymous. Circular 316, 1956.
Summarizes replies to a committee questionnaire to highway departments and large cities relative to pavement salvage evaluation.

2. "Salvaging Old Pavements by Resurfacing—Summary of Replies to Committee Questionnaire." Anonymous. Circular 413, 1960.
Summarizes replies to questionnaire to highway departments relative to methods of subgrade restoration for rigid-type pavements, methods used as a preventative for reflection cracking, and methods used or under test for evaluation of pavements befor and after resurfacing.

Highway Research Board Bibliographies:

1. "Salvaging Old Pavements by Resurfacing, Annotated." Anonymous. Bibliography 21.
A single volume in two sections, each separately indexed, one section covering rigid-type overlays and the other overlays of the flexible type. References total 256 with annotations for each entry.

Discussion

WILLIAM G. WESTALL, Supervising Engineer, Airfield Program, Portland Cement Association.—The paper prepared by Mr. Gould provides a comprehensive summary of committee activities and the significant developments since 1947 in the field of pav ment resurfacing. This report will be of great value in establishing the current statu of pavement resurfacing and in pointing the direction the committee should take in future investigations.

The purpose of this discussion is to supplement statements made by the author in paragraphs three and 5 of his conclusions.

The reference to concrete overlays contained in paragraph 3 is quoted as follows:

"Little, if any, progress is indicated by highway departments in the development of scientific means to evaluate the additional strength provided by various thicknesse of rigid type overlays...."

The accuracy of this statement is in no way questioned. The available reports and records indicate that the design of concrete resurfacing for highway pavement has generally been on a trial-and-error basis with thickness determinations based on the experience and judgment of local paving engineers. The evaluation of such resurfaci has been dependent on its performance under traffic. This type of evaluation has se ous shortcomings. If the resurfaced pavement shows early distress, there is no way of determining the degree of design deficiency. On the other hand, if the resurfacing performs adequately over a long period of time, there is no existing method for chec ing the possibility of over-design. In either case, the engineer is placed in a quanda

The trial-and-error approach is understandable in view of the fact that well-estab lished design criteria have been lacking. Tests conducted in recent years, however, have provided data for the development of design equations that are more realistic a less conservative in comparison with the formulas previously used.

For many years concrete resurfacing courses were designed on the theory that th strength of the two slabs was equal to that of a single slab having a thickness equal to the square root of the sum of the squares of the pavement and resurfacing.

$$h = \sqrt{h_r^2 + h_e^2}$$

here

h = thickness of required single slab, in inches;
h_r = thickness of resurfacing, in inches;
h_e = thickness of existing slab, in inches;

r

$$h_r = \sqrt{h^2 - h_e^2} \tag{2}$$

This method of analysis is theoretically correct only when the old pavement and the esurfacing slab are of the same stiffness and act as two independent beams deflecting qually under load, with no bond between them. Traffic tests on overlay pavements ave provided evidence that this formula will yield thicknesses which are very conserva- ve. Also, there is definite evidence that the bond and friction between the resurfacing nd existing slab are sufficient to cause them to act to some extent as a single unit ather than independently as assumed in the preceding formula. The U.S. Army Corps f Engineers, which has conducted more tests on overlay pavements than any other gency, makes this comment regarding the formula in Appendix II to their Rigid Pave- ent Design Manual (1):

"The results of the traffic testing at Lockbourne No. 1 and No. 2 and Sharonville o. 2 indicated that the above relationship was approximately correct when a leveling ourse, cushion course or bond-breaking course was placed between the two slabs, and at the relationship was too conservative when the overlay was placed directly on the se slab without purposely destroying the bond between the slabs."

Using a coefficient to express the condition of the existing pavement (as will be il- strated later), both the Corps of Engineers and Portland Cement Association use the eviously stated formula for calculating the required overlay thickness when bond tween the two layers is prevented by the use of some form of separating course.

After their test data demonstrated that the foregoing formula was too conservative r the design of overlays that would be partially bonded, the Corps of Engineers de- loped a revised empirical formula which expresses this relationship of the required erlay thickness to the single slab equivalent and the existing pavement:

$$h_r = \sqrt{h^{1.87} - h_e^2} \tag{3}$$

This equation gives lesser pavement thicknesses for the partially bonded condition ich results when no measures are employed to prevent bond. After the coefficient presenting pavement condition has been explained, an example will be given com- ring the overlay thickness given by this equation with the thickness given by Equation

Since concrete pavements considered for resurfacing will have variable structural lue depending on their condition, it has been necessary to introduce a coefficient, to express the pavement condition. The Corps of Engineers has used the following lues for C:

C = 1.0 - when the existing pavement is in good condition.
C = 0.75 - when the existing pavement has initial joint and corner cracks due to loading, but no progressive cracks.
C = 0.35 - when the existing pavement is badly cracked or crushed.

Using the coefficient C, the two basic equations for expressing overlay thickness uld become:

$$h_r = \sqrt{h^2 - Ch_e^2} \tag{4}$$

ich is the equation for use when bond is prevented;

and

$$h_r = \sqrt{h^{1.87} - Ch_e^2} \quad (5)$$

which is the equation for use when partial bond will be obtained.

As an illustration of the difference between the two equations, it is assumed that the existing pavements in both cases are 6 in. thick, the required thickness of an equivale single slab is 9 in. and the condition of the existing pavement in each case is such that C = 0.75. The overlay thickness required where bond is prevented would be

$$h_r = \sqrt{9^2 - (0.75x6^2)} = 7.35 \text{ in.}$$

The overlay thickness required where partial bond exists would be

$$h_r = \sqrt{9^{1.87} - (0.75x6^2)} = 5.82 \text{ in.}$$

The difference in thickness of the required overlays is 1½ in. or 20 percent less thickness where partial bond is obtained.

While these empirical equations can hardly be classed as "scientific means" of evaluating the additional strength provided by concrete overlays, their value as design criteria has been established in tests conducted by the Corps of Engineers in the development of design criteria for airfield pavements. The test program included 21 different test items of rigid overlay on rigid pavement where a "partial bond" conditio existed. Loading on the overlay sections ranged from a 20,000-lb single-wheel load to a 325,000-lb multiple-wheel gear load. The test sections were trafficked to either a predetermined number of coverages or to failure, depending on the adequacy of desig The Rigid Pavement Design Manual (1) is again quoted with reference to the tests:

"The Pavement Overlay Investigation was initiated for the purpose of obtaining dat to aid in the formulation of design criteria for overlay pavements. This objective wa accomplished in stages by construction of a series of full-scale test sections. After completion of testing of each successive test section, the results were analyzed and formulated into tentative design criteria. Each test section incorporated the results of previous projects and included new variables of loading, type and thickness of overlay, thickness and strength of the concrete base pavement, strength of subgrade, gea configuration, and total test load.... The equations used for determination of concrete overlay thickness have been developed from a correlation of theoretical develop ments and actual test results."

The design criteria based on the extensive investigations of concrete overlays by the Corps of Engineers should provide dependable guidance for highway engineers. I should be pointed out that the Corps has made further revision to the design equation used for partially bonded concrete resurfacing with the required overlay thickness expressed as

$$h_0 = \sqrt[1.4]{h_d^{\,1.4} - Ch^{1.4}} \quad (6$$

in which

h_0 = thickness of concrete overlay, in inches;
h_d = thickness of required single slab, in inches;
C = coefficient for pavement condition; and
h = thickness of existing slab, in inches.

This equation has been compared with the equation

$$h_r = \sqrt{h^{1.87} - Ch_e^2}$$

used previously in this discussion (and in Portland Cement Association literature) as he basis for design of partially bonded overlays. In the range of normal resurfacings hat would be applicable to highways, the two equations result in overlays with less than /10-in. difference in thickness. The Corps has found this revised formula more feasible or use in designing either exceptionally thick overlays for thin pavements or thin overays for thick pavements. These design requirements are seldom encountered exept in dealing with pavements for military airports. Design agencies may prefer to se the revised Corps of Engineers formula, however, since it will provide a dependable nethod for the design of concrete overlays for any combination of pavement and overlay hickness.

The tests conducted by the Corps of Engineers have conclusively proved that the omposite pavement has greater load-carrying capacity when the concrete overlay is artially bonded to the base slab. This evidence, together with other comparatively ecent developments, should lead to serious consideration of the advantages of fully onded resurfacing as a means of strengthening existing pavements.

Development studies by the Portland Cement Association during the past several ears have demonstrated the feasibility of bonding two layers of pavement together by conomical methods. A report of the laboratory results was published in the Proeedings of the Highway Research Board, Vol. 35, 1956 (2). The practicability of field onstruction methods for placing bonded resurfacing has been demonstrated on comaratively large-scale projects built on airfield pavements during the past four years 1). All the PCA test slabs and large-scale projects referred to utilized portland ement grout as a bonding agent. Recent repetitive load tests on full-scale slabs, built utdoors at the Portland Cement Association Laboratories, indicate that a composite avement of two bonded layers has the same strength as a monolithic slab of the same ickness. Using the cement grout bonding method, the Corps of Engineers constructed 11-in. overlay on a 17-in. base slab at Sharonville, Ohio. This overlaid pavement as tested in comparison with a single-layer 28-in. slab by trafficking with a test rig hich applied a dual-tandem gear load of 325,000 lb on the pavement. After more than),000 coverages with this loading, it was concluded that the bonded section performed a monolitic slab. This conclusion was based, not only on the equivalent durability the layered section, but also on deflection measurements and strain gage readings.

The performance of bonded overlays in test installations is such as to indicate that is type of construction is feasible and economical when structural improvement is cessary. Pavements on two airports, one civil and one military, were strengthened this method within the past two years. A 5-in. bonded overlay on an aircraft parkg apron is scheduled for construction early this year by the U.S. Navy.

The performance of these resurfaced pavements should provide information for rther evaluation of this method of construction.

In paragraph five of his conclusions, Mr. Gould states: "Reflection cracking for gid-type overlays, regardless of thickness, may not be a problem since no studies this nature have been reported to the committee."

In this connection it is necessary to report that joints and random cracks in the base vement will generally be reflected in the concrete resurfacing unless some preventae measures are taken. The practice generally used to prevent joint reflection can easily described by quoting again from the Corps of Engineers design manual:

"Joints in the overlay pavement will coincide with all joints of the base pavement. is not necessary for joints to be over like joints." (1)

The second statement in the quotation requires some amplification. Many old conete pavements were built with expansion joints at relatively short intervals. Expanon joints can usually be omitted in the resurfacing or placed at much longer intervals. ntraction joints should be placed over the expansion joint location. This procedure plies to overlays that are partially bonded. In placing thin layers of bonded resuring, it is considered necessary to match existing joints in both location and kind.

Some success has been experienced in preventing reflective cracking by the use of parating courses between the base slab and overlay. There is not sufficient data ailable, however, to indicate the minimum thickness of separating course that will completely effective. There are indications that any type of bond breaker will reduce amount of reflective cracking, but as has been previously discussed, the use of a nd breaker creates the requirement for a thicker overlay.

If the old pavement is badly cracked, the use of distributed steel is probably the most dependable method of minimizing cracking in the resurfacing. This is true for both bonded and partially bonded overlays. If distributed steel was used in the origina pavement, the amount of steel in the resurfacing should be based on the thickness of the overlay slab. If the old slab does not contain distributed steel, the amount of steel should be based on the combined thickness of the two slabs.

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