An Overview of Determination of Cement Concrete Abrasion in Pavement

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Abstract-*Cement Concrete has been increasingly used in pavements during recent years. In addition to strength, abrasion resistance is another important property of Cement Concrete. Abrasion resistance is a most important characteristic of concrete pavements. Many pavement surfaces are required to remain in a smooth and dust Free State even in the face of severely abrasive loads. These may include rolling steel wheels and even impact from heavy wheel loads. Concrete pavements on the other hand must be able to resist a degree of grinding from sand trapped beneath vehicle wheels, or the continual rubbing and mild impact from wheelloads. This paper provides a general overview on study of the determination of abrasion resistance of concrete. There are different test methods to determine the abrasion resistance of concrete subjected to number of various types of abrasion. There are number of different tests used in various countries and it is clear that there is no single test that adequately measures the abrasion resistance of concrete under all conditions. This paper provides the summary and classification of the various abrasion tests and focused on the abrasion resistance of concrete for pavement applications.*

I. INTRODUCTION

Deterioration of concrete surfaces occurs due to various forms of wear such as erosion, cavitations, and abrasion due to various exposures. Abrasion wear occurs due to rubbing, scraping, skidding, or sliding of objects on the concrete surface. This form of wear is observed in pavements, floors, or other surfaces on which friction forces are applied due to relative motion between the surfaces and moving objects. Concrete abrasion resistance is markedly influenced by a number of factors including concrete strength, aggregate properties, surface finishing, and type of hardeners or toppings. A large number of previous studies have indicated that concrete abrasion resistance is primarily dependent upon compressive strength of the concrete. The factors such as air entrainment, water-to-cement ratio, type of aggregates and their properties, etc. that affect the concrete strength, therefore, should also influence abrasion resistance. In general, hardened paste possesses low resistance to abrasion. In order to develop concrete for high abrasion resistance, it is desirable to use hard surface material, aggregate, and paste having low porosity and high strength. Data on the abrasion resistance of concrete is needed to determine appropriate mixture proportions in order to make abrasion resistant concrete. A limited amount of published work is available on abrasion resistance of concrete, especially concrete for pavement applications. Therefore, this review paper is concentrated on abrasion resistance of concrete pavement applications.

II. FACTORS ON ABRASION RESISTANCE

The abrasion resistance of concrete is directly related to its strength and the increase in resistance is principally due to an increase in cement content and reduction of water content. The quality of the mortar is important - the hardness of the coarse aggregate only becomes significant under exceptionally abrasive conditions i.e. when the surface matrix has been worn away. The good wear-resistance properties of concrete arise mainly from its being a very rich concrete and less from the aggregate it contains. In general, well-graded natural sands free from soft materials should be used, with coarse aggregates which need only be especially selected for conditions of exceptionally heavy wear. Coarse aggregates should be free from soft sandstone or soft limestone[]. Apart from the direct relationship between abrasion resistance and concrete compressive strength, other factors also have a major effect on abrasion resistance. Methods of construction such as the finishing process can have an influence. Curing and the type of surface treatment are other important factors.

The accelerated abrasion test method adopted in that research project allowed a reliable determination of surface wear against time. The extent of abrasion was measured by a micrometer at intervals of 5, 10, 15 and 30 minutes of test. The results show that the finishing technique, especially the use of repeated power trowelling, has the greatest influence on abrasion resistance, followed by curing, then concrete mix proportions. That study also found that:

- A change from Grade 40 to Grade 25 concrete will result in an increase in wear of about 20%;

- not using the appropriate finishing technique can increase the wear by 3 to 4 times;
- repeated power trowelling is an effective finishing technique to improve abrasion resistance;
- the use of surface treatments, such as polyurethane or epoxy, were found to significantly enhance the abrasion resistance;
- failure to cure the slab compared to covering with polythene sheeting can result in more than doubling the wear; and
- Surface hardeners seemed to provide initial improvement but once the hardener layer was penetrated, the abrasion resistance reverted to that of an untreated concrete.

The repeated power trowelling using a solid disc power float machine consisted of three periods of power trowelling separated to allow the bleed water to reach the surface and evaporate.

III. LITERATURE REVIEW

In analyzing the various factors that affect abrasion resistance, it is essential to have some understanding of the abrasion test that was used. Results taken at face value without due consideration to the test used may be meaningless! Furthermore it has been able to reconcile many of the apparently contradictory findings of different authors by a consideration of the tests they used. Clearly there is a difference between deep abrasions relative to shallow, or uniform grinding relative to indiscriminate attack, or high crushing/impact relative to light rubbing. Alexander (1984) considers that the 'most difficult part of an abrasion test is the correct interpretation of the results'. Therefore, whenever appropriate, in citing the work undertaken by an investigator, reference will be made to the test that was used by the author. This may take the form of citing the abbreviated name of the test, e.g. 'ASTM C418 is used to represent: Test method for abrasion resisting by sand blasting'. Alternatively a test may be referred to by a 'generic name', e.g. the generic name used for ASTM C418 is 'impacting fine abrasive'. Other typical generic names for other tests include 'impacting steel balls', 'rolling steel balls', 'sliding fine abrasive', etc. The first word of the test's generic name indicates the abrasive action (either impact, rolling or sliding), while the rest of the name indicates the abrasive medium. Quite often the abbreviated name and the generic name are both given in the text. This nomenclature streamlines the presentation, yet still gives the reader an appreciation of the mechanism of wear. With regards to the pavement applications, one key area where there is limited data is in the abrasion resistance of concrete.

While ASTM does have several standard tests for abrasion, the tests are more geared to rolling wheel, impact, or hydro- abrasion, while in pavement applications problems occur mainly from grinding abrasion. Additionally, there is a lack of information regarding the abrasion resistance of quaternary mixes. Finally, it is known that the presence of moisture and abrasive fines increases deterioration[2] but many tests for abrasion resistance do not incorporate these parameters. Abrasion results from dynamic forces and displacements that are cycled many times. In concrete ties, abrasion could be caused by some combination of rubbing of the tie pad, grinding of abrasive fines, and the impact between the wheels and road surface. Papenfus reviewed the main factors that contribute to abrasion resistance in concrete, especially for concrete pavements. These factors include concrete strength, binder content and type, aggregate characteristics, air content and porosity, and surface treatment.

Significance and Use

The three test methods[] provide simulated abrasion conditions, which can be used to evaluate the effects on abrasion resistance of concrete, concrete materials, and curing or finishing procedures. They may also be used for quality acceptance of products and surface exposed to wear. They are not intended to provide a quantitative measurement of length of service. The equipment used by each of these procedures is portable and thus suitable for either laboratory or field testing. The three procedures determine the relative wear of concrete surfaces as follows:

Procedure A—The revolving-disk machine operates by sliding and scuffing of steel disks in conjunction with abrasive grit.
Procedure B—The dressing-wheel machine operates by impact and sliding friction of steel dressing wheels.
Procedure C—The ball-bearing machine operates by high-contact stresses, impact, and sliding friction from steel balls.
Diagrams of three machines meeting these specifications are shown in Fig. 1, Fig. 2, and Fig. 3.

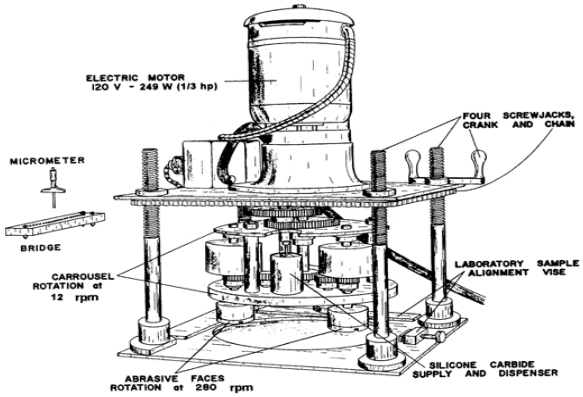

FIG. 1 Revolving Disks Abrasion Test Machine

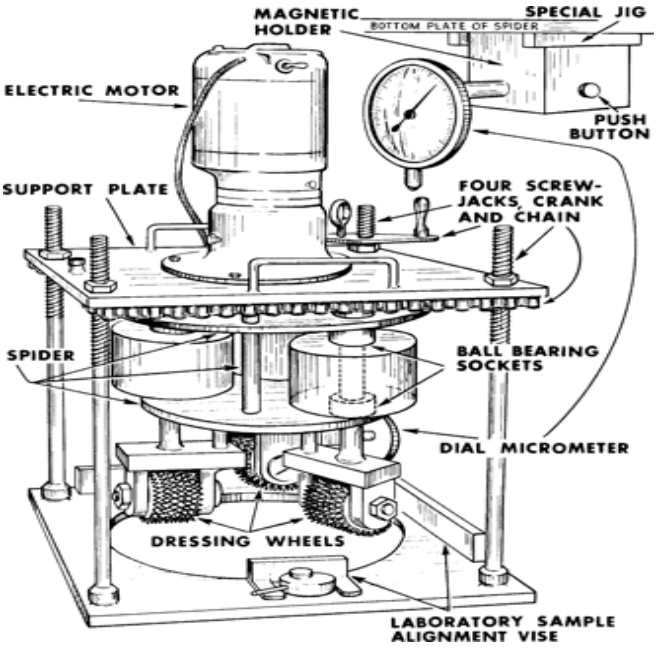

FIG. 2 Dressing Wheel Abrasion Test Machine

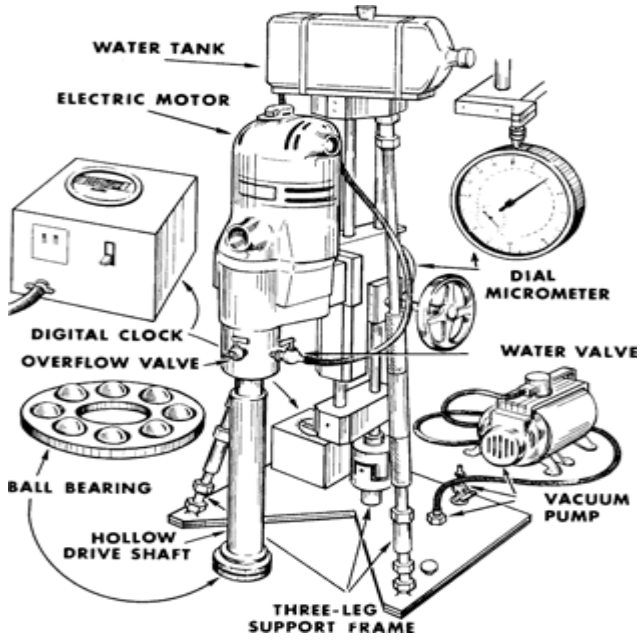

FIG. 3 Ball Bearing Abrasion Test Machine

The above test method covers three procedures for determining the relative abrasion resistance of horizontal concrete surfaces. The procedures differ in the type and degree of abrasive force they impart, and are intended for use in determining variations in surface properties of concrete affected by mixture proportions, finishing, and surface treatment. They are not intended to provide a quantitative measurement of the length of service that may be expected from a specific surface. The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the inch-pound units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of each other. This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use[]. Other procedures are available for measuring the abrasion resistance of concrete surfaces in addition to the three procedures contained in this test method. Consideration should be given to Test Methods C944 and C418. The test method most closely representing service conditions should be used.

IV. CONCLUSIONS

The abrasion loss of high strength concrete can be estimated from compressive and flexural strength results. Abrasion (wear) resistance is achieved by controlling a whole series of factors. It is not sufficient to specify just an appropriate concrete strength. This must be complemented by proper construction practices, e.g. placing, compaction, finishing and curing. Where very high abrasion resistance is required, special aggregates or dry shake may be needed, either added to the surface or as a topping.

It is clear that there is no single test capable of simulating all types of field abrasive action. Table. 1 Presents the suitability of different code procedures with respect to various abrasion tests. Y-Represents the appropriate code according to abrasion type.

Abrasion type	**AST M C 418**	**ASTM C 779**			**AST M C 944**	**AST M C 1138**
		A	**B**	**C**		
Light to medium traffic	Y	Y	Y		Y	
Heavy and steel wheeled traffic	Y		Y	Y	Y	
Heavy steel wheeled & track vehicles, heavy trucks wheeled traffic		Y	Y	Y		
Hydraulic structures	Y					Y

Table 1 Appropriate code according to abrasion type

The paper presents a classification and detailed discussion of different tests being currently used to measure abrasion resistance of concrete. From the comparative study, it is clear that ASTM C 799 test procedure is suitable for simulating most of the traffic related abrasive actions, while the abrasion resistance of concrete in hydraulic structures like dams and spillways etc., can be better studies using underwater abrasion test of ASTM C 1138.

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