# TEXAS TRANSPORTATION INSTITUTE

# TEXAS HIGHWAY DEPARTMENT

# COOPERATIVE RESEARCH

VIBRATION OF CONCRETE

2-8-54-1

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## VIBRATION OF CONCRETE

1. Damping Capacity of Hardened Cement Paste and Mortar in Specimens Vibrating at Very Low Frequencies, D. G. Cole and D. C. Spooner American Society for Testing and Materials, Proc. (1916 Race St., Philadelphia, Pa. 19103), Vol. 65, pp. 661-667, 1965.

   The damping capacities of cement paste and mortar specimens vibrating at frequencies from 0.16 to 4 cps and with strain amplitudes up to $150 \times 10^{-6}$ were measured. The ends of the specimen were clamped to the midpoints of metal beams. The apparatus was suspended from a rigid beam by wires connected to the centers of gravity of the inertial beams. The specimens were vibrated by drawing adjacent ends of the inertial beams toward each other and releasing them. The relative position of the ends of the inertial beams were sensed by a noncontacting electronic pickup, and the logarithmic decrement was measured directly using an oscilloscope and camera. The logarithmic decrement increased linearly with strain amplitude over the range of strains investigated. At frequencies below 2.5 cps the logarithmic decrement increased with decreasing frequency. The authors suggest the process responsible for the low frequency damping effect are the same ones that govern creep.

2. A Vibration Flow Test for Cement Mortars, S. L. Weinland and L. A. Weinland, Materials Research & Standards (1916 Race St., Philadephia 3, Pa.), Vol. 4, No 4, pp. 165-167, April 1965.

   The flow of cement mortars under vibration was measured during early hydration. Mortars were tested containing the following accelerators and retarders: calcium chloride, calcium lignosulfonate, salicylic acid, triethanolamine, and sodium monomethyl siliconate. Specimens were formed in hemispherical plaster molds and left undisturbed until tested. They were then vibrated and photographed at timed intervals.[1] Relaxation occurred during the first 60 min. in the plain mix, and some of the mortars containing admixtures also showed flow relaxation during the initial stages of hydration.

3. Some Observations on the Revibration of Concrete at Different Frequencies, Ovidiu Mirsu and Cecil H. Best, Kansas Experiment Station, Special Rept. No. 45. Kansas State University (Manhattan, Kansas) Bull., Vol. 48, No. 6, June 1964, 24 pp.

   The influence of amplitude and frequency of revibration at different times on the ultimate strength of high-strength concrete is considered. In particular, the effect of different frequencies (designed to influence the large aggregate, the small aggregate, and the concrete paste itself) on the ultimate strength, the density, and the durability of the concrete were noted. To help in interpreting the results of these tests, an additional series of tests was performed on specimens of mortar alone. Because of the large number of specimens tested and the large number of parameters involved, the results provide a basis on which more extensive and more definite work may be planned.

4. Vibrated Fly-Ash Concrete, G. V. Gemerling and A. N. Chernov. Stroit. Materially i Betony, Chelyabinek, Sb. 1964, 83-7 (U.S.S.R) Ref. Zh. Khim. 1964, 17M118. Chemical Abstracts, Vol. 62, No. 7, P. 7490, March 1965.

Experiments conducted to improve the technology of production of fly ash concrete from stiff mixes described. Material consumption in kilograms per cubic meter of concrete was: cement, 250; electrical power station ash, 500; unslaked lime, 50; Al powder, 1.7; and water, 230, 250. The properties of fly ash concrete prepared by ordinary swelling and vibration swelling were studied. In vibration swelling, the optimum water: solid ratio can be decreased by 35 to 40 percent; in this case the ash-cement mix had the appearance of moist earth and thinned thixotropically during vibration. The optimum temperature of vibration swelling was 40 to 50 deg. After mixing with water the prepared gas concrete mix was placed in a mold and vibrated at a frequency of 3,000/min. (amplitude 0.1 to 0.3 mm) for 40 to 60 sec. Such a mixture does not swell without vibration. Vibration caused a vigorous movement of the mix particles, products from the reaction of aluminum power with calcium hydroxide were removed from the reaction zone, and swelling occurred rapidly. The mix sets quickly after vibration is stopped and can be heat-treated without preliminary curing, thus shortening the time required to prepare the finished product by 4 to 5 hours. After 12 hr. of steaming at 85 to 90 deg., the samples (dried to a constant weight) had a strength of 55 kg/sq cm and passed water and frost resistance tests. Water absorption was 31.2 percent, softening factor was 0.83, shrinkage was slight and the dynamic elasticity modulus was 35,000 kg/sq cm.

5. Investigations of Internal Vibration of concrete, Lars Forshead Nordiak Betong (Drottning Kristinas vag 26, Stockholm 70, Sweden) Vol. 7, No. 1, pp. 83-114, 1963.

At the Concrete and Soil Laboratory of the AB Vibro-Verken, Stockholm, Sweden, a testing method has been devised for determining the radius of action of an internal vibrator at various instants after the insertion of the vibrator into the concrete.

Most of the tests described in this paper were made in a form 180 cm in length, 40 cm in width, and 50 cm in depth. The side walls of the form consisted of concrete slabs, 25 cm in thickness, which transmitted vibrations in a much smaller degree than timber forms. The increase in the radius of action with the time was determined by photographing the top surface of the concrete in the form.

The tests on internal vibrators provided with vibrating heads 60 mm in diameter were performed at varying frequencies and amplitudes. These tests showed that the radius of action manifestly increased as the frequency became higher, up to about 10,000 cpm. As the frequency was increased above this value, the radius of action increased at a slower rate. After the frequency had re ched an optimum value of 12,000 cpm, the radius of action decreased. An increase in the amplitude caused an increase in the radius of action at all frequencies. Internal vibrators should be designed so as to combine a large amplitude with an optimum frequency.

The radius of action increased as the weight of the vibrating head became greater on condition that the frequency, the amplitude, and the diameter of the vibrating head wer unchanged. Furthermore, the radius of action increased with the diameter of the vibrating head in practice carried with it an increase in the weight of the vibrating head.

Comparative tests on various internal vibrators were carried out by means of a fluidity meter which was specially devised for this purpose. The effects of the frequency and the amplitude exhibited the same trends as in the comparisons between the radius of action of the vibrators.

Test specimens, 140 cm in length, 15 cm in width,and 55 cm in depth, were compacted with internal vibrators which differed in vibration characteristics. After hardening, twelve 15 cm cubes were sawed from each past specimen, and were used for determining the compressive strength and the unit weight. The variations in the compressive strength and in the unit weight were found to be small in a comparison between different vibrators as well as in a comparison between points within the radi of action of the vibrators. The greatest differences in the compressive strength (calculated as mean values for twelve cubes) between various test specimens were 5 percent. A trend observed in all tests was that those vibrators which had the greatest radius of action in the fresh concrete also produced the highest compressive strength of the hardened concrete. Those cubes which were nearest to the top surface of the test specimen had a strength which was 2 to 5 percent lower than that of the other cubes.

6. The RRL Vibrating Wire Strain Gauge, Highways and Bridges and Engineering Works (60 Cambridge Rd., New Malden, Surrey, Eng.) Vol. 31, No. 1511, P. 9, July 24, 1963.

A vibrating wire strain gage designed by the Road Research Laboratory of the D.S.I.R. is an economically priced transducer for the accurate determination of slowly varying and long term internal strains in concrete. The gage consists of a pretensioned fine steel wire supported between two end flanges, and enclosed in an acrylic tube. An electromagnetic plucking coil is mounted centrally in the wall of the tube, adjacent to the wire.

As the strain in the concrete is proportional to the square of the frequency of vibration the gage provides a simple means for assessing internal strains in concrete media. Extensive tests in the laboratory, and subsequent field use of the gage had proved its long term reliability.

The R.R.L. gages are already widely used. Some applications and advantages claimed for the gage are as follows: permits internal measurements on concrete road slabs, reinforced concrete structures in situ; can be used for measuring slowly varying strains due to restrained thermal warping, expansion and contraction, shrinkage and creep; high accuracy of reading attainable (0.5 in./in.) unaffected by leads up to at least 500 yds in length; low elasticity offers minimum interference with parameters being measured.

7. A Note on the Effect of Frequency on the Behaviour of Fresh Concrete During Vibration, H.Green and A. B. Roberts, Magazine of Concrete Research (52 Grosvenor Gardens, London, S.W.1) Vol. 15, No. 44, pp. 115-117, July 1963.

The behavior of fresh concrete during vibration varies with the frequency of the vibration applied. For each mix there is a particular frequency at which a drastic change in the acceleration of the mold and the mix takes place during vibration with constant power input. The strongest concrete is produced at this frequency of vibration.

8. The Compaction of Mortar and Concrete by Vibration, H. Green, Civil Engineering and Public Works Review (8 Buckingham St., London W.C.2) Vol. 57, No. 669, pp. 467-469, April 1962, No. 670 pp. 632-634, May 1962.

Vertical linear vibration was applied at frequencies from 35 to 245 cycles per sec to mixes of cement and single-sized aggregates in the range of size up to 3/8 in. and of cement and combinations of these aggregate sizes corresponding to the coarsest and finest gradings of sand complying with B.S. 882; 1954. Rich and lean mixes with three water contents were tested for each combination of aggregates. The results show that the frequency for which maximum strength is obtained (the optimum frequency) is influenced by the particle size of the aggregates and tends to increase as the size of the particle is increased.

The main conclusion drawn from this investigation of vibration of mortar and concrete cubes with a moving-coil vibrator providing vertical linear sinusoidal motion are as follows: (1) the optimum frequency of mixes made with single-sized aggregates is influenced by the particle size of the aggregate and tends to increase as the size of the particle is increased; (2) the optimum frequency of rich mixes containing a graded aggregate increases as the size of particle predominating in the graded aggregate is increased; (3) the cube strength at the optimum frequency is from 6 percent to 30 percent greater than the average cube strength of the mixes over the range of frequencies applied in the tests; (4) the strength often drops markedly at frequencies slightly higher than the optimum frequency; (5) the strength of a mix vibrated at any given frequency increases with an increase in the applied acceleration but at a decreasing rate; (6) the water content of the mix does not appear to have an important influence on the optimum frequency.

9. The Effects of Aggregate Grading and Vibration Frequency on the Compaction of Concrete by Table Vibration, Harry Green. Proc. Institute of Civil Engineers (Great George St., London, S.W.1) Paper No. 6603, pp 377-390, August 1962.

The difficulties that prevent satisfactory coordination of the published work on the compaction of concrete by vibration arise principally from differences in the modes of vibration and in the definition of the properties of the concrete mixes used. In the tests described in this paper, simple harmonic leniar vibration has been applied and extraneous influences have been reduced to a minimum.

A preliminary investigation had shown that when mortars and concretes were made from cement paste and single-sized aggregates, there was a particular frequency tended to increase with increase in particle size. Similarly when mortar mixes made with graded aggreges were compacated by vibration, the mixes with aggregates containing a majority of large particles had higher optimum frequencies than mixes with aggregates containing a majority of small particles.

This paper reports an investigation made to determine whether the same phenomenon applies to concrete mixes made with graded aggregates of large maximum size. The mines were vibrated in 4-in. cube molds at eight frequencies ranging from 25 to 230 cycles per sec. (1,500 to 13,000 cycles per min.) with an acceleration of 4 g. For each concrete mix in the range tested, with a few exceptions, it was found that one frequency produced the best compaction as judged by compressive strength. This frequency increased as the proportion of sand in the mix was decreased, that is to say, as the means particle size was increased.

10. The External Vibration of Concrete, J. Kilek, Civil Engineering, and Public Works Review ( 8 Buckingham St., London, W.C.2), Vol. 54, No 633, pp. 321, 325, March 1959.

A review of the principles of compaction of concrete by vibration relevant to the object of this paper is given. The influence of acceleration, amplitude and frequency is discussed and a generalized theory of compaction is suggested. A distinction is made between two aims in using vibrators for concrete purposes and an experiment is described to find the influence on these aims of the frequency of vibration. Practical recommendations are quoted for external vibration including guiding points for the estimation of the type and the number of vibrators needed. Results of a survey of external vibrators are also included.

11. Effect of Internal Vibration of Concrete Mixtures Upon the Entrained Air, F. H. Blandin and O. Larsen, Illinois Highway Engineer (Illinois Association of Highway Engineers, 209 Jefferson Avenue, Elgin, Ill.), Vol. 11, No. 2, 2nd Quater, pp. 2-4, pp. 10, 1959.

In accordance with the requirments of the Standard Specifications for Road and Bridge Construction, concrete produced for the Illinois Division of Highways must have an entrained air content of 3 to 5 percent of its volume. For concrete in its plastic state, it is relatively simple to see that this requirement is complied with k. However, the work performed on the concrete during placement is known to remove some of the air, and some apprehension exists as to whether the hardened concrete may at times be left with substantially less than the desired amount of entrained air.

Since the development of the high pressure method for determining air contents of hardened concrete, some consideration has been given to the feasibility of conducting an investigation to study the loss of entrained air by internal vibration .K. It was decided, however, first to make a few pilot tests to simulate the loss in air content as related to period of vibration, and to determine if the air that remains in the hardened concrete is sufficient to prevent reduction in durability. With this object in view, a number of small batches of concrete were prepared and, after various periods of internal vibration, were made into specimens for testing in alternate freezing and thawing with intermittent determinations of their dynamic moduli of elasticity to observe their degree of deterioration during the tests.

Although it would be difficult to correlate the degree of vibration imparted to the small batches of concrete with that obtained in actual practice at various locations in structures, the conclusions as stated below probably are generally applicable to mixtures initially having air contents of 4 percent.

(1) In mixtures of dry consistency, say less than 2-in. slump, it appears unlikely that the entrained air content will be reduced below 3 percent by a reasonable amount of internal vibration.

(2) In mixtures of wet consistency, say more than 5-in. slump, it appears that the entrained air content may easily be reduced below 3 percent by even a moderate amount of vibration.

(3) The results of the durability tests indicate strongly that when the air contents are reduced below 3 percent, the loss includes some of the air that is beneficial in imparting durability to the concrete.

(4) The resistance of concrete to freezing and thawing, regardless of air content, is reduced by an increase in the water-cement ratio, as would occur through arbitrary addition in mixing water to increase slump.

(5) It may be inferred from certain ASTM methods of conducting freezing and thawing tests that durability factors of 70 to 200 cycles, and 60 to 300 cycles of the test, are reasonable low limits for the durability factor. If this be taken as a criterion, the data indicate strongly that inferior resistance will result if the entrained air by reason of vibration is reduced below 3 percent.

(6) The results of the tests undoubetly are of sufficient interest to warrant further investigation.

12. Effects of Revibrating Concrete, C. A. Vollick, Journal of the American Concrete Institute, (P.O. Box 4745 Rrecord Station, Detroit 19, Mich.), Vol. 29, No. 9; Proceedings, Vol. 54, pp. 721 732, March 1958.

Tests were made to determine the effect of revibration at intervals of 1 to 4 hr after placing on properties of hardened concrete. Results show effect of revibration on compressive strength of concretes designed with varying cement contents and different admixtures. Effect on bleeding and hardening time is also given.

The conclusions are based on the results of tests performed on mixes discussed in the paper, in which revibrated concrete was vibrated the same total length of time as concrete vibrated only once. Different combinations of materials and increased vibration or revibration may produce different results.

Concrete that is to be revibrated must be properly proportioned with suitable materials. All other factors relating to good concrete practice must be followed.

Revibration increases the 28-day strength of concrete. Average maximum increase in strength is 13.8 percent.

Revibration increases the apparent strength indicated by the impact hammer at 28 days. Maximum strength gain is obtained when the concrete is revibrated 1 or 2 hr after placing.

Revibration up to 4 hr placing has no effect on the final hardening time of concrete as measured by a reading of 4,000 psi with the Proctor needle. Revibration may increase the time required to obtain a reading of 500 psi on the Proctor needle as much as 1 hour.

Revibration concrete bleeds more than concrete given the same total amount of vibration initially.

Revibration does not cause segregation, but it has no significant effect on uniformity of compressive strength measured at 2-in. intervals from top to buttom of 28 inch. block.

Appearance of concrete can be improved by revibration.

The delay between placement and revibration that is necessary to increase compressive strength of concrete is less critical if a set retarder is added to the concrete.

13. A method has been devised for determining the thickness of concrete road slabs by measuring, at the surface of the slab, the velocity of propagation of vibrations at audio and ultrsonic frequencies.

A vibration generator acting vertically on the surfave of the slab produces vibrations of known frequency which are detected by a pick-up. The pick-up is moved progressively away from the generator and positions are noted at which the vibrations at the generator and pick-up are in phase. The distance between successive positions gives the wavelength ($\lambda$) of the vibrations; the velocity of propagation is determined from the product of the wavelength and frequency.

In the frequency range from 1,000 c/s to 4,000 c/s, the vibrations are identified as flexural waves and their velocity (V) depends upon the frequency, the thickness (T) and the elastic constants of the concrete slab. At frequencies above 50 kc/s, the velocity is constant, and the propagation becomes sensibly independent of the frequency and the thickness of the slab, i.e., it is then the Rayleigh wave velocity ($V_R$) of surface waves in the concrete. From the theoretical analysis, a graph is prepared giving the variation of $V/V_R$ with the quantity and this enables the thickness of the slab to be calcualted from the experimental results.

Tests have been made on slabs of thicknesses varying from 4 to 9 inches, some slabs being laid directly on the subgrade and some on prepared bases of soil cement and hoggin. The results have generally been satisfactory and, in many cases, the dimensions of cores drilled from the slabs have agreed with the calculated values of thickness to within ±10 percent.

14. Gap-Graded Aggregates in Vibrated Concrete, T.E.H. Williams, Engineering (London), Vol. 179, No. 4662, pp. 693-698, 1955. Building Science Abstracts, Vol. 28, No. 11. p 322, November 1955. Highway Research Abstracts, April 1956.

Any benefit arising from use of gap-graded aggregates in concrete production arises from the decreased wedging action caused by omission of intermediate sizes. A fundamental analysis is made of this phenomenon of particle interference, and those principles governing the action of gap-graded aggregates in vibrated concretes are established. The criterion from particle interference is the relation between the mean void diameter for a compacted coarse (principal) aggregate and the mean projected diameter of a fine (secondary) aggregate. When the former diameter is less than the latter, particle interference occurs. Expressions for calculation of these two diameters are given. This criterion applies when the principal aggregates consist of one or two groups of "single-size" particles. Concrete aggregates should be gap-graded if particle interference effects are to be avoided. Maximum bulk-density (pcf.) is generally obtained when the secondary aggregates contain the maximum possible number of groups of "single-size" particles. Relations between aggregate grading and fixed-time vibration, and between aggregate grading and vibration to complete compaction are established. The vibrating table and measuring apparatus used in the experiments are described.

15. Compaction by Vibration, Western Construction, Vol. 30, No. 12 p. 42, December 1955. Highway Research Abstracts, March 1956.

Compaction of solid particle mixtures by means of vibration is well recognized by everyone who has filled a container with such household items as sugar or salt. Also, the vibrating of concrete mixtures is a well established engineering practice to produce denser products and reduce the volume of voids. The corresponding application of a vibrating force to compact soil, with particular reference to highway bases, is incorporated in a vibrating roller of recent development. This vibrating compaction reaches greater depths than possible by the use of heavier rollers which do not employ this effect.

This machine weighs three tons and consists of: (1) a roller 48 inches in diameter and 58 inches in width and (2) an independent vibrating exciter driven by a 25-horsepower diesel motor which adds a vibrating force to the roller with a frequency of 1,600 rpm. The unit can be pulled by any type tractor.

Among the many experiments made to determine the capacity of the roller, a sandy material with a Proctor density of 109 pounds and a 12-percent optimum moisture content was used. The material' was composed of 12-percent coarse sand, 80 percent fine sand, and 8 percent silt and clay. The test was made to determine under what operating conditions the required Proctor density could be reached and surpased. Standard density measurements were made after each pass of the roller, with samples taken at 1-, 2- and 3-foot depths before and after. The test showed that at a 2-foot depth an optimum compaction was produced with two pases of the roller operating at a frequency of 1,500 rpm. and a propagation velocity of 2 mph/

It should be pointed out that good compaction has been secured on strata more than 2-feet below the surface, which is difficult if not impossible to secure with purely static rollers of similar weight. On the particular soil tested, when, when loosely distributed, some tests at 5-foot depths showed substantial increase in density after 2 static and 4 dynamic passes. This type of combination might lead to new applications for vibratory compaction.

A modification is construction methods which would permit the increase in depth of individual layers during construction ought to be considered where vibratory compaction is used, because of the substantial saving in construction time and money. This is particularly true in work on large dams, highway fills, and the backfilling of trenches.

16. Concrete Mix Design for Vibration, Highways and Bridges and Engineering Works (Cresent House, Ashford, Midlesex, England) Vol. 23, No. 113., pp. 6,8, March 21, 1956. Highway Research Abstracts, May 1956.

It has been assumed by some engineers that any concrete mix which can be compacted by hand is suitable for compaction by vibration. That this was not true was stated by J. M. Plowman, in a paper read recently to meetings of the Reinforced Concrete Association. He said that many mixes which behaved admirably under mild treatment in hand compaction showed signs of severe segregation or violent rotational instability when vibrated.

Tests in progress are designed to determine the resistance of various gradings to segregation and rotation, not their desirability from other aspects such as workability.

Segregation may be defined as the separation of concrete mix into its constituent parts, the cement paste collecting in one area, the large aggregate in another, the water in a third area, etc. Segregation may take place in horizontal or vertical planes, the horizontal type occurring when table or vertical vibration is used and the vertical type mainly with immersion vibrators. In the latter case, and hears that the vibration has been too long and that the mortar has been drawn to the vibrator, whereas on this problem is not far advanced and results will be reported at a later date.

Rotational instability is less well known although it probably occurs as frequently as segregation, the latter mainly in large sections while the former is most noticeable in narrow sections, such as beams.

Throughout the tests, the maximum size of the aggregate was 3/4 inch, being either Thames Valley sand and gravel (in the first series) or crushed granite (9n the second). Pilot tests indicated that the greatest rotation would take place with a mix of 1:4.8 and a water-to-cement ratio of 0.35. These proportions were used throughout the first and second series of tests.

With experiences of the unstable mixes it became apparent that there were three types in instability and not one: (a) rotation with one side higher than that opposite and the mix moving from one to the other; (b) cylindrical rotation with two opposing sides lower than the center, the whole in the form of a cylinder; and (c) eruptive with air being violently expelled from the center of the mass and drawn in at the sides.

Arbitrary degrees in instability were decided by eye, five divisions being recognized.

1. Stable. The upper surface remaining horizontal after the initial settlement of the concrete.

2. Tendency to rotate. The upper surface being inclined without lateral movement, frequently associated with (c).

3. Slow rotation. As (a) but sometimes as (b) with lateral movement at about 3 feet per minute.

4. Medium rotation. Usually as (b), lateral movement between 3 and 20 feet per minute.

5. Fast rotation. As (b) with (c) in the faster cases, the lateral movement being greater than 20 feet per minute.

The results of these tests may be summarized thus: (1) Certain gradings which may be defined by curves, show a tendency to rotate when a differential acceleration is applied. (2). lap-length and bond, (3) residual strength of bond, and (4) variation of results on the bond strength of the particular bar considered. For vibrated concrete having a 28-day cube strength of about 4,500 psi, and with all types of bar spacing and arrangement testing, the regulation design load (1948 Code of Practice) shows a high factor of safety. The variation in results is small. Failure of bond under overload will reduce the bearing capacity by about 10 percent for each bond failure. Close spacing of bars will not affect the bond in concrete which has been fully compacted by vibration. If cracks in beams occur at not less than six bar-diameters apart, then it is thought possible that the full load in the bars may be transferred to the concrete between cracks.

18. The Influence of Variables in the Vibration of Concrete, J. M. Plowman. Concr. Build. Concr. Products, 1953, 28 (9), 205-7 Road Abstracts (London) Vol. 21, No. 2, p 26, February, 1954. Highway Research Abstracts, April 1954.

The effects of frequency, acceleration, and time of vibration on the strength of a concrete mix of constant proportions, water-cement ratio and grading are described. Frequency of vibration has little effect and the compaction time is directly proportional to the proportion of water in the mixture. For a given mix there is a certain "critical" water-to-cement ratio, for which the strength is independent of the acceleration; at lower ratios, increased acceleration results in higher strength but at higher ratios the reverse relation obtains and the concrete is unsuitable for vibration. Some gradings of aggregate also render the concrete unsuitable for vibration, and in molds the mix has rotational instability; air is sucked into the mass during vibration and the strength of the concrete is reduced.

19. Effect of Methods of Using Small Vibrating Screeds on the Depth of Compaction of Concrete, R.H.H.Kirkham, Surveyor and Municipal and County Engineer (England), Vol. 113, No 3257, p. 673-675, August 7, 1954. Highway Research Abstracts, October 1954.

Recent experiments have shown that if a concrete road slab is to be fully compacted, the correct surcharge must be provided i.e., the height above the forms to which the concrete is spread must be correct. Hand-operated vibrating screeds, however, are generally made so that the vibration causes the screed to slide along the forms during the finishing pass; in practice, the screed is often used in this way for the compacting pass as well, in order to reduce the amount of work. When the vibrating beams is of normal rectangular section, experience has suggested that such an arrangement causes some of the surcharge to be screeded off, which results in poor compaction at the bottom of the slab.

It was considered desirable, therfore, to examine whether the beam could be adapted in any way so that full compaction in a slab 8 inches thick could be achieved when it was allowed to slide along the forms or whether it was essential for the beam to be moved along in steps and lifted on to the uncompacted concrete at each step. The modifications included the provision of some form of leading edge of the use of the beam at an angle to the vertical so that its front edge was above form level.

20. Design of Concrete Mixes for Compaction by Surface Vibrators, R.H.H. Kirkham. Symposium on Mix Design and Quality Control of Concrete, London, May 11-13, 1954. Highway Research Abstract September 1954.

The design of a mix suitable for compaction by vibration in a concrete road differes only from that for other structures because of the small variations in strength and workability which can be accepted. Gnerally there is little permissible variation in the water-to-cement ratio necessary to meet the specification but where experience has been gained with particular materials and methods, the known limits of the variation in strength, when these are small, can be used to permit an increase in water-cement ratio and a reduction in cement content and can thus be used to give more exonomical mixes.

The selection of the correct aggregate-to-cement ratio is more difficult. Concrete to suit all types of surface vibrator should have between "low" and "very low" workability, the value being chosen from experience to suit the vibrator to be used, the maximum size of the coarse aggregate, and the grading of the sand. The aggregate grading must be adjusted so that the concrete will not be likely to segregate or prove difficult to finish in relatively thin slabs, and allowance must be made for the shape of the particles. An estimate of the proper proportions can be made, but it is not precise,and trial mixes are generally required before the exact proportions can be settled. Before a more-precise method can be developed, compaction by surface vibration, in which the characteristics of the vibrator to be used are simulated.

These procedures (the use of the actual variation in strength to determine the water-cement ratio and of a vibration test to determine the water-cement ratio and of a vibration test to determine the aggregate-cement ratio) appear likely to lead to the development of improved methods of quality control and made efficient compacting machines. It would be necessary, however, for some changes to be made in the form of the specifications.

21. Pressure of Concrete on Shuttering, Concrete and Constructional Engineering, Vol. XLVI, No. 6, June, 1951. (London). Highway Research Abstracts, July, 1951.

The probably pressures on vertical shuttering in Table I are based on data derived from tests and given by M. Guerrin in a recent number of "La Technique de Travaux". It is seen that even if the extreme cases of liquid and earth-damp concretes are ignored, the pressures vary by 75 percent to 150 percent depending upon the consistency. If the rate of placing is increased from about 1/3 cu.yd. per hour to about 1-1/3 cu yd. per hour, the pressures increase up to 25 percent and this is especially so if the concrete is in wide walls or beams. If the concrete is in thin walls or beams or is vibrated, the rate of placing appears to be of little importance. An increase in temperature causes a decrease in pressure; for example, the pressure may decrease from 25 percent to 40 percent if the temperature rises from 60 to 100 deg. F. The "silo" effect in narrow shuttering may result in a decrease up to 10 percent with vibrated concrete. The "silo" effect does not occur with liquid concrete, but in the case of "earth damp" concrete it may reduce the pressure by a half. Tests in the USA have shown that with liquid concrete the pressure may be about 50 percent greater for a rich mixture than for a lean mixture. The influence of the nature of the shuttering is negligible, although for ordinary concrete the pressure on steel shuttering may be about 3 percent greater than on wooden shuttering.

22. Vibration and the Rheology of Fresh-Mixed Concrete, R. L. Hermite; Rev. Mat. Constr., C. 1949, (405), 179-87. Building Science Abstracts, Vol. XXII, (New Series), No. 12, December, 1949, London. Highway Research Abstracts, June, 1951.

The deformation occurring in cement and concrete mixes when a shearing force is applied was measured in a mould comprising a ring in two sections. The upper section could be rotated in relation to the lower, and was provided with an annular piston for applying pressure to the concrete. Measurements made on neat cement paste, dry aggregate used in concrete, and on the same aggregate saturated with water, and measurements made with a channelled cylinder inserted vertically into the concrete show that the coefficient of internal friction (k) decreases with increasing water content, and that the deformation at rupture by slipping ($\Theta$) depends on the particle size distribution of the cement. The workability of a concrete is defined as the reciprocal of the product of these two values, k and θ. The degree of segregation was measured by placing the fresh concrete in an elongated box and determining the center of gravity before and after vibrated concrete acts as a liquid. For the concrete in question, the viscosity of this liquid was determined by the falling-ball method was 61 gm./cm./sec. The forces of vibration and their effect on the concrete are treated mathematically. The pressure of the concrete on the walls of the mould increases directly as the applied weight up to 0.2kgm./sq. cm. (410 lb. per sq.ft.) and then increases very slowly. In relation to this investigation reference is made to the work of Forslind and Bergstrom (Swedish Cement and Concrete Inst., 1948).

23. The Rheology of Fresh Cement and Its Vibration, by Robt. L'Hermite. Rev. materiaux construction trav. publ., Ed. C., No. 405, 179-87 (1949); cf. Forsling and Bergstrom, Swedish Cement and Concrete Ins., 1948. Chemical Abstracts, Vol. 44, No. 3, February 10, 1950. Highway Research Abstracts, April, 1950.

To measure the deformation which takes place when a shearing force is applied, a mold was constructed in the form of a ring in two sections. The upper section could be rotated in relation to the lower, and was provided with an annular piston for applying pressure to the concrete. Measurements made on pure cement paste, the dry aggregate used in concrete, and on this same aggregate saturated with water. Measurements made with a channeled cylinder inserted vertically into the concrete showed that the coefficient of internal friction decreased as the proportion of water increased; and that the deformation of rupture by slippage depends upon the particle size distribution. The workability of a concrete is defined as the reciprocal of these two values. Segregatability was measured by placing the fresh concrete in an elongated box and determining the position of the center of gravity before and after shaking. Measurements were also made of shearing strength before, during, and after vibration. It was concluded from the data that, within certain limits of external pressure, the vibrated concrete acts as liquid. The viscosity of this liquid was measured by the falling-ball method and a value of 61 g. per cm. per sec. was found for the concrete under investigation. The vibratory forces and their effects on the concrete are treated mathematically. The pressure of the concrete on the walls of the mold increased directly with the applied weight up to 0.2 kg. per sp. cm., then to increase very slowly. -- E.R. Rushton.

24. Nuclear Device Features Push-Botton Testing of Compaction Highway Builder (Associated Pennsylvania Constructors, 600 N. Third Street, Harrisburg, Pa.) Vol. 40, No. 7, p. 26, July 1961.

A new push-botton nuclear device for making rapid measurements of the density and moisture in soils, aggregates and pavements has been developed.

The portable instrument, called the "Hydro-Densimeter" will permit inspectors (or contractors) to take reading of both the moisture and density of material being compacted in just 60 sec. A series of three readings to verify unformity of these conditions take less than 5 min.

The "Hydro-Densimeter" system differs from other such nuclear devices in that it is composed of only two components, instead of three, and employs a radioactive material the use of which does not require licensing by the Atomic Energy Commission.

Engineers field-testing the new method have reported that it takes inspectors only 1/7th as long to measure moisture and density on compaction work as the traditional rubber balloon, sand replacement, and oven-drying m thods.

The "Dyro'Densimeter" is composed of two units - a "probe" and a "counter". The probe (8 in. x 3 in. x 14 in.), containing a radioactive material (radium beryllium), is placed flat on the surface of the compacted area, meterial, or pavement, where it radiates fast neutron rays and gamma rays to the depth desired. The separate counter (11½ in. x 11 ½ in. x 11 in.) counts the number of gamma rays recovered during a 60 sec period inversely indicates the density of the material; and the number of fast neutrons reveals its moisture content.

The surface probe can measure density at depths of 2½ to 12 in.; moisture to a depth of 4 in. (Another probe is also available which can be used to measure density at greater depths. It is a small cylindrical tube which can be lowered through a 2-in hole to the desired depth.)

Major uses of the "Hydro-Densimeter" are: (a) density measurements and compaction control in earthfill, subbase and base of highways, air strips, and earth dams; (b) non-destructive testing of concrete pavements; (c) control of stabilizer distribution in bitumen stabilized soils; (d) on-location determination of optimum moisture curves for compaction control; (e) testing of compacting equipment; (f) location of leaks in earth dams, canals, dikes,etc.; (g) checking of moisture content in sand at premix concrete plants; (h) measurement of density in stockpile materials (coal, grain, etc.) for accounting purposes; (i) checking soil stability; (j) location of pilings for bridges; (k) evaluation of fills, backfills, and borrow pits in mines, earth embankments, highways, etc.; and (1) checking for potential pavement failures.

The new equipment is available from Viatec Division of Tellurometer, Inc., U. S. Distributors of the well-known Tellurometer System for distance measurements, 206 Dupont Circle Cuilding, Washington, D.C.