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VIBRATION OF CONCRETE

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SURVEY OF LIBRARY FACILITIES PROJECT

VIBRATION OF CONCRETE

1. Cole, D. G. and Spooner, D. C. DAMPING CAPACITY OF HARDENED CEMENT PASTE AND MORTAR IN SPECIMENS VIBRATING AT VERY LOW FREQUENCIES. American Society for Testing and Materials, Proc. (1916 Race St., Philadelphia, Pa. 19103), Vol. 65, pp. 661-667, 1965. HR Abstracts, November 1966.

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 x 10 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 as oscilloscope and camera. The logarithmic decrement increased linearly with strain amplitude over the range of strains investigated. At frequencies below 205 cps the logarithmic decrement increased with decreasing frequency. The authors suggest the processes responsible for the low-frequency damping effects are the same one that govern creep..

2. Weinland, S. L. A VIBRATION FLOW TESTS FOR CEMENT MORTARS. Mater. Res. & Stand., 1964, 4 (4), 1965-7, Road Abstracts, Vol. 31, p. 202.

An investigation into the behaviour of cement during the initial stages of hydration is described. The method used is a modification of the flow table test (Conrow's method); the specimen is vibrated and its deformation is measured as a function of vibration time. Because of their effect on the rate of stiffening of cement mortars, accelerators and retarders were included in the study. Measurements were taken by means of a reflex camera mounted above a vibrator and a stopwatch. The composition of the mortars used are given and the flow curves for different admixtures are shown.

3. L'Hermite, Robt. THE RHEOLOGY OF FRESH CEMENT AND ITS VIBRTTION. 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 at 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 a 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 concrete on the walls of the mold increased directly with the applied weight up to 0.2 kg. per sq. cm., then to increase very slowly.

4. L'Hermite, R. VIBRATION AND THE RHEOLOGY OF FRESHLY-MIXED CONCRETE. 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 coefficients of internal friction (k) decreased with increasing water content, and that the deformation at rupture by slipping (θ) 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 0.2 kgm./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).

5. Manche, H. OBSERVATIONS ON THE DURATION OF VIBRATION OF CONCRETE. Rev. Mater. Constr., 1950, (415), 148-50. Road Abstracts, Vol. XVIII, No. 12, p. 185, December, 1951, London. Highway Research Abstracts, February 1952.

Tests have been carried out to determine (a) the vibration time necessary to produce concrete of maximum strength, (b) the influence of excessive or insufficient vibration on concrete strength, and (c) the extent to which vibration time may be varied without sensibly altering the quality of the finished product. Among the conclusions drawn are: (1) Prolongation of vibration time does not affect the quality of concrete generally used. (2) There is an economic limit of duration of vibration which satisfactorily fulfils technical requirements. If the water/cement ratio is reduced by 1 percent, vibration time must be three times as long, and this gives as increase in strength of 4 percent.

6. Venkatramaiah, S. MEASUREMENT OF THE WORK DONE IN COMPACTING A KNOWN WEIGHT OF CONCRETE BY VIBRATION. Mag. Concr, Res., 1951, (5), 89-96. Road Abstracts, Vol. XVIII, No. 9, September 1951. Highway Research Abstracts, March 1952.

An electrically operated vibrating table is described which was designed to measure the work done in compacting freshly mixed concrete. Tests were carried out to determine frictional and electrical losses; these were deducted from the total work done in compacting a known weight of concrete. Graphs are presented which show the relation, for 3 different mixes, between work put into the concrete for complete compaction and (a) compacting factor, (b) water-cement ratio.

7. CONSOLIDATION OF CONCRETE IN ROADS AND RUNWAYS. Concrete and Constructional Engineering, Vol. XLVII, No. 5, pp. 155-156, May 1952. HR Abstracts, Sept. 1962.

The method of consolidating the concrete in the runway at the Munich-Reim Airport in Germany is described by Ing. W. Tzschentke in "Strasse und Autobahn" for August 1951. The slab is 12 in. thick and, in parts, 16 in. thick. At first the concrete was laid in three layers of 4 3/4 in., 4 3/4 in., 4 3/4 in., and 2½ in., but this method required three sets of concrete mixing and placing plants, and there was a considerable interval between the laying of the bottom course and the completion of the joints in the top course

To solve the problem, the slab was laid with a bottom course of 9½ in., on which the reinforcement was placed, and a top course 2½ in. thick. The slab was 25 ft. wide. The lower course was compacted with vibrators of the poker type, which were pulled through the concrete. Vibrators with a frequency of 9,000 vibrations per minute were used, and it was found possible to achieve complete compaction to a depth of 9½ in. For this purpose, the vibrators were set 2 ft. apart and 1 ft. from the edge of the longitudinal joint, so that there were six vibrators over a width of 12 ft. 5 in. The leads to the vibrators and the transformer were mounted on a movable cradle on a carriage 25 ft. wide moving on rails. The compaction of the lower course of one of the four runways was successfully done by three passages of the machine with the vibrators at different depths each time.

This use of internal vibrators necessitated a wetter concrete than usual.

The vibrators had at first a tendency to work to the surface, and three men each looked after two vibrators and kept a distance of 2 ft. between them. In future provision is to be made for a suspension mechanism on the cradle to keep the vibrators at a constant depth and spacing, so that the vibrators as well as the cradle and stage can be looked after by one man.

8. Kirkham, R. H. H., and Whiffin, A. C. EXPERIMENTS ON THE VIBRATION OF FRESHLY PLACED CONCRETE. Dept. of Scientific and Industrial Research, Road Research Laboratory (England). Reprint from The Engineer, February 15, 1952. Highway Research Abstracts, October 1952.

Particulars are given of an experimental vibrating machine designed by the Road Research Laboratory to study the effects of the variables involved. The variables studied so far have been those considered most likely to have the greatest influence on the design of compacting machines, i.e., the acceleration and amplitude of the vibrating beam, together with the number of vibrations imparted per given length of slab.

Three series of tests were made to investigate the effect of varying: (1) the amplitude (the number of vibrations per foot run and the acceleration of the beam being kept constant); (2) the number of vibrations applied per unit length of the slab with constant amplitude and acceleration; and (3) the acceleration of the vibrating beam with constant amplitude and number of vibrations per foot run.

The conclusions below may be drawn from the experiments on concrete slabs 18 in. thick, made with a 1:2½;5/0.6 mix of workability 0.80 ± 0.005, using a rectangular shoe, frequencies of vibration between 1,500 and 6,000 vibrations per minute, accelerations between 1g and 12g, amplitudes between 0.004 in. and 0.064 in. and forward speeds of travel between 1 ft. and 8 ft. per minute.

1. When the vibrator was operated at constant acceleration and constant number of vibrations per foot of travel, increase of the amplitude of the eam (which was, of course, accompanied by decrease of the frequency of vibration) increased the depth of compaction.

2. At constant acceleration and amplitude of the beam, slower speeds of travel (i.e., increase of number of vibrations per foot run) increased the depth of compaction.

3. When both the amplitude of the beam and the number of vibrations per foot run were fixed, the depth of compaction was not dependent on the acceleration of the vibrator beam.

4. The density attained at a given depth in the concrete was dependent on the peak value of the particle velocity attained at that depth and on the total work done on a particle at that depth.

5. For the concrete employed in these tests in slabs 18 in. thick, the depth of compaction increased with the total movement which could be transmitted by the beam; that is, with the amplitude of the beam multiplied by the number of vibrations per foot run. The depth of compaction attained a limiting value at approximately 12 in.

6. The best surface finish was obtained at high frequencies of vibration, the high frequencies tending to produce a sandpaper finish, while low frequencies left some parts of the surface unsealed.

9. Larnach, William J. CHANGES IN BOND STRENGTH CAUSED BY RE-VIBRATION OF CONCRETE AND THE VIBRATION OF REINFORCEMENT. Magazine of Concrete Research, No. 10, pp. 17-21, July 1952. Highway Research Abstracts, October 1952.

By means of pull-out tests the effects of (1) re-vibration of partially set concrete in which reinforcement is located, (2) the application of vibration directly to the reinforcement during concrete placement and (3) the direct vibration of bars protruding from partially set concrete are studied. The results indicate that treatments (2) and (3) have little effect, and that treatment (1) may result in a decrease of about 30 percent in the average bond stress for the horizontal reinforcement used.

The tests indicate that, in general, high values of the average unit bond strength can be attained by vibrated concrete, placed at low water content.

The maximum reduction (about 30 percent) in the bond strength of horizontally cast specimens occurred when concrete surrounding reinforcement was re-vibrated after a period of three hours from casting. Direct vibration of reinforcement during casting, or vibration of reinforcement protruding from partially set concrete, had little effect on the average bond strength, though the variablity of replicate tests was increased. The results indicated that greater variation in bond strength than that experienced was unlikely, if the interval between casting and subsequent treatment were increased beyond the maximum of 6 hr. in the tests.

In general, the tests were carried out using the driest mix compatible with good compaction (except where the water content was the variable under investigation). It is shown that aggravated effects of a given treatment are likely if the water content is increased above that required to produce the workability necessary for placing. In practice, therefore, it is necessary that adequate control be placed on water content of the mixture if the concrete or reinforcement is likely to be subjected to any of the treatments investigated.

10. Childs, L. D. and Nussbaum, P. J. PRESSURES AT FOUNDATION SOIL INTERFACES UNDER LOADED CONCRETE AND SOIL-CEMENT HIGHWAY SLABS. Proc. Amer. Soc. Test. Mater., 1962, 62, 1243-63. Road Abstracts, Vol. 30, p. 151.

Discussion, 1263. (See Abstract No. 629.) Published material on layered system investigations is briefly reviewed (22 listed references). Details are given of a study by the Portland Cement Association of interface pressures under concrete slabs and soil-cement bases. The results are compared with theoretical values computed by layer theory analysis. Pressures on the subgrade were distributed for the full width of the concrete for interior loads on all slabs. Granular subgrades increased the effectiveness of stress distribution. Pressures in sub-bases and subgrades were not much affected by variations in thickness of a granular sub-base. The thickness of soil-cement bases has a significant effect on the pressure transmitted to the subgrade.

11. DEPTH VIBRATORS FOR CONCRETE COMPACTION FOR THE PERIOD FROM 1960 to 1965. Stroi. i dorozh. Mash., 1963, 8 (3), 35-7. (In Russian). Road Abstracts, Vol. 30, p. 107.

Specifications are listed for various types of internal vibrator produced or to be developed in the U.S.S.R. The application is discussed of pneumatic, flexible shaft and electromagnetic vibrators with outer diameters of from 34 to 180 mm.

12. Kirkham, R. H. H. PRESENT TRENDS IN RESEARCH AT THE ROAD RESEARCH LABORATORY. Struct. Concr., 1962, 1 (6), 257-67: Consult, Engr, 1963, 23 (4), 448-51. Road Abstracts, Vol. 30, p. 80.

Information is given on a number of items on which research is proceeding at the Road Research Laboratory, Harmondsworth, on the use of concrete in roads. A laboratory vibrator has been developed which simulates the compaction of concrete in a road and so facilitates the design of mixes suitable for compaction by surface vibration. Research is in progress to develop an improved test for the resistance of concrete of freezing and thawing. Work on quality control of concrete includes (a) acceleration of the strength testing procedure by curing specimens at higher temperatures than usual, (b) control based on rapid analyses of the fresh concrete rather than on strength, and (c) formulating procedures for making the best use of the strength results obtained. The full-scale experimental roads at Oxton and Alconbury Hill have confirmed that the thicknesses recommended for heavily trafficked roads in Road Note No. 19 are f the right order. A further experimental road has been constructed on the Grantham by-pass to obtain information on weight of reinforcement in relation to joint spacing; this road includes long, continuously reinforced slabs. An experimental road prestressed by means of hydraulic jacks has also recently been constructed. Other work discussed includes an investigation into the effect of the characteristics of vibration on the compaction of concrete (see also Road Abstr., 19621, 29, No. 1026), methods of patching concrete roads and methods of raising settled concrete slabs.

13. Green, H. COMPACTION OF MORTAR AND CONCRETE BY VIBRATION. Civ. Engng, Lond., 1962, 57 (669), 467-9; (670), 632-4. (With French and German summaries.) This paper was prepared at the Building Research Station, Watford. Road Abstracts, Vol. 30, p. 59.

Vertical linear vibration was applied at frequencies from 35 to 245 cycles per second 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 decreased.

14. Bennett, E. W. and Gokhale, V. G. SOME EXPERIMENTS ON THE COMPACTION OF CEMENT PASTE, MORTAR AND CONCRETE BY VIBRATION OF DIFFERENT FREQUENCIES. Indian Concrete Journal (Cement House, 121 Queen's Rd., Bombay, India), Vol 41, No. 11, pp. 421-428, Nov. 1967. Journal of American Concrete Institute, Vol. 65, No. 7 p. 575, July 1968. HR Abstracts, September 1968.

In spite of the extensive application of vibratory compaction, knowledge of the action of vibration of fresh concrete is still incomplete. The article describes tests to determine which characteristic of vibration has the most beneficial effect on compaction. It was found that, at a constant power input, the frequency has a remarkable effect on the strength of cement paste and mortar. Some experiments are described on the compaction of mortar by a compound vibration.

15. Sugiuchi, H. STUDY OF VIBRATION OF CONCRETE. REPORT 1: REVIEW OF LITERATURE. U.S. Army Engineer Waterways Experiment Station (Vicksburg, Miss.), Tech. Rept. No. 6-780. June 1967. 26 pp. HR Abstracts, November 1967.

This review was conducted to summarize and critically evaluate previous work dealing with or relevant to internal vibration of fresh concrete, and to determine approaches for further studies concerning vibration of concrete. It has been found that the previous studies, with some exceptions, have not approached the subject from a consistent viewpoint of internal vibrations as a vibratory process, i.e., all of the many and complex parameters were not tied together to relate to the process of mechanical vibration. The primary difficulty lies in trying to observe the process in a too-complex condition. The recommendation of this review is that the mechanics of internal vibrators be determined and related to the behavior of fresh concrete under vibration so that the influence of each parameter may be more clearly defined.

16. Davis, Raymond E. and Davis, Harmer E. COMPACTION OF CONCRETE THROUGH THE USE

OF VIBRATORY TAMPERS. American Concrete Journal, June 1933, pp. 365-372, Vol. 29. ACI Index, p. 233.

Summarizes findings of tests made to study relative advantages of vibratory tamping as compared with hand tamping with regard to: ease of placement, form pressures, homogeniety of concrete, bond of new concrete to old, strength, sensity, and durability of concrete. Both internal and external vibratory tampers were employed.

17. Powers, T. C. VIBRATED CONCRETE. American Concrete Journal, June 1933, pp. 373-381, Vol. 29. ACI Index, p. 233.

Following field tests of internal vibrators, laboratory investigations of the relation of strength to cement-voids ratio, of the proper mix characteristics for vibration, and freezing and thawing tests were made. It was found that for a mix to be placed successfully by vibration it must be plastic or become plastic under vibration. The relationship between the cement-voids (voids = water plus air) ratio is substantially the same for vibrated as for hand-placed concrete.

18. Reagel, R. V. VIBRATORY FINISHING MACHINE FOR CONCRETE PAVEMENTS. American Concrete Journal, June 1933, pp. 391-396, Vol. 29, ACI Index, p. 233.

A vibrating-screed type finishing machine and a standard type Ord finisher were used in a series of tests on a concrete paving project. The results of the tests definitely indicate that leaner mixes can be satisfactorily finished by the vibratory method without sacrificing quality of the concrete. This indicates that a potential saving in the cost of materials can be affected.

19. Hathaway, C. M. PRACTICAL APPLICATION OF VIBRATION. American Concrete Journal, Mar.-Apr. 1935, pp. 420-423, Vol. 31. ACI Index, p. 240.

The use of mechanical vibrators in Illinois for placing concrete in the construction of bridges has had satisfactory results. Conclusions in regard to requirements of internal vibrators, preferable practices in their use, precautions in building forms, and permissible changes in the concrete mixes and their slumps are discussed in detail. The use of internal vibrators has cut down the cost of concrete structures by reducing the manpower required for spading concrete 40 to 70 percent and decreasing the required amount of cement 5 to 10 percent in the cost of form building.

An experiment in the use of surface vibrators on pavements is mentioned briefly. It was found that a leaner mix could be used and that a drier consistency was necessary. The pavement edges were, at time, honeycombed. Some surface scaling also developed, but it is uncertain whether this was due to the use of the surface vibrator.

20. Reagel, F. V. VIBRATED CONCRETE IN PAVEMENT SLABS. Mar.-Apr., 1935, American Concrete Journal, pp. 424-428, Vol. 31, ACI Index, p. 240.

Experiments indicate that the vibratory method of placement and finishing concrete pavements, with attendant savings in the cost of materials, is one of the most important recent developments in its field. Development of the equipment has lagged, however, so that maximum benefits are not yet available.

The two general types of vibrating equipment used in Missouri have produced good economical concrete pavement. Certain difficulties and limitations encountered are discussed without attempting to condemn or compare either type.

21. Johnson, W. R. VIBRATION OF CONCRETE. American Concrete Journal, Mar.-Apr. 1935, pp. 429-431, Vol. 31. ACI Index, p. 240.

The selection of a vibrator to be used on a job is dependent on the type of form in which the concrete is being placed. Large open forms, using batches ranging from 2 to 6 cu yd, with aggregate graded up to 9-in. maximum size require a two-man vibrator. Thin walls ahd heavily reinforced sections should use internal vibrators operated by one man. Form vibrators are used where internal vibrators cannot be used, such as tunnel linings and concrete pipe. One vibrator will effectively handle from 12 to 36 cu yd per hr. Formwork need not be changed but should be made as tight as possible to prevent leakage. Drier concrete can be used when placing with vibration; sand in the mix can be reduced 2 to 4 percent. Determining the end point of vibration is a matter of experience which is soon acquired by the foreman or inspector. For measuring the effectiveness of equipment, work two or more vibrators of different type in the same form at the same time. Lower costs of vibrated concrete are due to saving in cement which amounts to one-half to one bag of cement per cu yd of concrete. The higher quality of concrete placed by vibration is due to drier mixes used, which means less free water, lower water-cement ratios, and less volume change.

22. Stanton, Thomas, E., Jr. VIBRATION OF CONCRETE ON SAN FRANCISCO-OAKLAND BAY BRIDGE. American Concrete Journal, May-June 1935, pp. 539-544, Vol. 31. ACI Index, p. 241.

Describes studies made by the California Division of Highways in 1932 on internal vibration of concrete and subsequent application of the results of these studies in drafting specifications for and the placing of concrete in the San Francisco-Oakland Bay Bridge, one of the earlier projects on which the internal type vibrator was used.

Some of the essential requirements and advantages of internal vibration in concrete construction are discussed. The paper includes a brief description of the 20 ft and 30 ft width pavement type vibrators used in placing and finishing the upper and lower roadways of the Bay Bridge.

23. Tuthill, Lewis H. VIBRATION AS AN AID IN PLACING BETTER CONCRETE. May-June 1935, American Concrete Journal, pp. 545-550, Vol. 31. ACI Index, p. 241.

Particular emphasis is placed by the author on proper handling and placing of concrete to assure full benefit of vibration as an aid in placing the most efficient mix, i.e., one having the practical minimum water and cement content. Vibrators are most effective when used to consolidate a uniform concrete placed in a horizontal layer, but their effectiveness is considerably reduced when they must also transport and remix concrete in the forms.

24. Jackson, F. H. HIGH FREQUENCY VIBRATION AS APPLIED TO THE CONSTRUCTION OF CONCRETE PAVEMENTS. American Concrete Journal, May-June 1935, pp. 551-556,

Vol. 31. ACI Index, p. 241.

Reviews the history of the development of high frequency vibration as applied to the construction of concrete pavements. Calls attention to the necessity of adjusting the consistency and the sand-coarse aggregate ratio if satisfactory results are to be secured and also to the fact that, if the maximum potential benefits resulting from vibration are to be realized, other units in the construction operation, such as mixer drum and conveyor bucket must be redesigned to handle much drier concrete than is at present possible.

25. Moreell, B. CONCRETE VIBRATING PRACTICES IN FRANCE. American Concrete Journal, Sept.-Oct. 1935, pp. 66-67, Vol. 32. ACI Index, p. 242.

Describes concrete vibrating equipment and practices in France up to the year 1933 and states that, in general, equipment is similar to the equipment in this country with one exception, viz., "floating per-vibrators." This piece of equipment is described. Internal vibration is greatly favored over vibration of forms but where the former is impracticable, vibrating of forms is practiced, although the ceonomy of compacting by vibration in lieu of hand-tamping was not as marked in France as in this country because of the lower wage scale.

26. Powers, T. C. OBSERVATIONS ON THE USE OF VIBRATION IN THE FIELD. American Concrete Journal, Sept.-Oct. 1935, pp. 74-79, Vol. 32. ACI Index, p. 242.

Field observations indicate that when vibrators prove unsatisfactory, the cause can be found among the following items: (1) poor management, (2) unsatisfactory methods of transporting concrete, (3) unwise selection of size or number of vibrators, (4) vibrators operating below normal, (5) improperly proportioned mixes. Improper choice and operation of vibrators are due to lack of experience. A field method for adjusting a mix to the requirements of the vibrator is given.

27. Committee 609. RECOMMENDATIONS FOR PLACING CONCRETE BY VIBRATION. American Concrete Journal, Mar.-Apr. 1936, pp. 445-457, Vol. 32. ACI Index, p. 244.

The adoption of high frequency vibrators for placing concrete has been more rapid than the progress in acquiring basic information on such factors as frequency, amplitude, size of vibrator, type of vibrator, period and method of application and others. In this preliminary recommended practice for vibration, many of the requirements are based on the well established fact and principles of concrete making. Items covered include: type of vibrator, number and capacity, forms, adjustment of mix, vibrating procedure, and effects of vibration.

28. Jackson, F. H. and Kellermann, W. F. THE EFFECT OF VIBRATION ON THE STRENGTH AND UNIFORMITY OF PAVEMENT CONCRETE. American Concrete Journal, Mar.-Apr. 1937, pp. 411-432, Vol. 33. ACI Index, p. 248.

Tests were made on full size pavement slabs, using regular construction equipment. Several well-known types of high frequency surface vibrators were investigated. Major indications were (1) that with equal cement contents, vibration increased flexural strength about 10 percent, (2) that, with equal water-cement ratios, vibration effected a saving in cement of about 10 percent and (3) that the uniformity of pavement concrete of 1-in. slump was markedly improved by the application of surface vibration.

29. Tuthill, Lewis H. and Davis, Harmer E. OVERVIBRATION AND REVIBRATION OF CONCRET American Concrete Journal, Sept. 1938, pp. 41-48, Vol. 35. ACI Index, p. 252.

Effects of overvibration are rarely encountered in cnncrete of medium and the drier consistencies, in the wetter consistencies horizontal stratification may result with detriment to durability. Tests show that as long as the concrete has not become so stiff that revibration will not restore plasticity, revibration benefits, does not harm concrete.

30. Welden, E. C. DURABILITY OF PAVEMENT CONCRETE--EXPERIENCE IN CONNECTICUT. American Concrete Journal, Apr. 1939, pp. 405-416, Vol. 35. ACI Index, p. 255.

Connecticut practice in the construction of concrete pavements has seen many changes, both in design, and methods of construction. Since the early twenties coarse and fine aggregates of good quality have been readily available. The use of a gravel or stone base under the pavement, and also the minimum amount of water necessary for workability of the concrete, has had much to do with the relatively good condition of the pavement concrete. Expansion joints and fillers in many cases have proved disappointing. Experience to date indicates that the use of vibrators with mixes of the proper consistency will improve the quality and durability of pavement concrete.

31. Ruettgers, Arthur. A QUESTIONNAIRE ON CONCRETE VIBRATION. American Concrete Journal, Jan. 1940, pp. 265-272, Vol. 36. ACI Index, p. 257.

Summarizes the opinions expressed by members of Committee 609, Vibration of Concrete, in reply to a questionnaire devised by the committee chairman. The questionnaire was instrumental in developing a program for the further work of the committee, by indicating (1) what truths or generally accepted findings regarding vibration as a means of compacting concrete have emerged from previous investigation and experience, and (2) what important phases of the subject remain to be investigated to remove them from the field of speculation and controversy.

32. Washa, George W. COMPARISON OF THE PHYSICAL AND MECHANICAL PROPERTIES OF HAND RODDED AND VIBRATED CONCRETE MADE WITH DIFFERENT CEMENTS. American Concrete Journal, June 1940, pp. 649-684, Vol. 36, ACI Index, p. 259.

Present results of a comprehensive series of tests on vibrated and hand-rodded concrete. The variables for each method of placement are five different mixes and five different cements. Particular attention has been paid to the lean mixes, the leanest vibrated mix being 1:6:12 by weight, with only 2.2 sacks of cement per cu yd of concrete. The results obtained indicate the effects of the variables on compressive strength, permeability, specific weight, adsorption, linear changes due to alternate heating and water soaking, modulus of elasticity, Poissons's ratio, shrinkage, and plactic flow.

33. Committee 614. RECOMMENDED PRACTICE FOR MEASURING, MIXING AND PLACING CONCRETE. (ACI 614-42). American Concrete Journal, June 1945, pp. 625-650, Vol. 41. ACI Index, p. 275.

An outline of the best practices for measuring and mixing the ingredients for concrete and for placing the finished product. The specific objective of these recommendations is maximum uniformity, homogeneity, and quality of concrete in place.

Among the topics covered are: measurement and batching of aggregates; batching cement; water measurement; mixers; charging and discharge operations; mixing time; ready-mixed concrete; avoidance of separation in placing operations; vibration; and general considerations such as construction joints and forms. The report also includes illustrations of good and bad concreting practices.

34. Higginson, Elmo C. SOME EFFECTS OF VIBRATION AND HANDLING ON CONCRETE CONTAINING ENTRAINED AIR. American Concrete Journal, Sept. 1952, pp. 1-12 Vol. 49. ACI Index, p. 314.

The effects of vibration, handling, and delay in placing concrete containing entrained air were evaluated in the laboratory with some check studies made on two large dam construction jobs. Curves of the test results show the rate at which vibration removes air from air-entrained concrete at various slumps. Loss of air caused by handling and delays in placing is determined. The effect of loss of air on the compressive strength and durability of the hardened concrete is evaluated. Evidence is presented that normal vibration does not materially affect bleeding, and that increased vibration may improve the surface appearance of concrete.

35. Meissner, H. S. COMPACTING CONCRETE BY VIBRATION. American Concrete Journal, June 1953, pp. 885-892, Vol. 49. ACI Index, p. 320.

Vibration compaction is one of the important advancements in concrete technology. There yet remains, however, something to be learned about the fundamentals of vibration and the characteristics of vibrators to make more efficient use of this method for compacting concrete. A description and classification is given of the various vibrators in use together with some discussion of their characteristics and the type of work for which they are adapted.

36. Bergstrom, Sven G. LABORATORY TESTS ON VIBRTTION OF CONCRETE. American Concrete Journal, June 1953, pp. 893-908, Vol. 49. ACI Index, p. 320.

A brief survey of tests dealing with pressures, displacements, and energy consumption in fresh concrete compacted by internal vibration. Three methods of determining the radius of action of the internal vibrator and the effects of variation in the radius of action with the concrete mix and with the vibrator characteristics are discussed. A graph presents some data on the energy consumption during vibration. Described is an apparatus for studying variations in the properties of fresh concrete with time of vibration. The type of these variations characterizes the fresh concrete in respect to required time of vibration and liability to segregation. Mention is made of a few test results concerning the relation between properties of hardened concrete and time of vibration.

37. Timms, A. G. APPLICATION OF VIBRATION TO CONCRETE PAVEMENT CONSTRUCTION. American Concrete Journal, June 1953, pp. 933-944, Vol. 49. ACI Index, p. 321.

Brief description and summary of tests and experience in the United States and Europe in vibrating pavement concrete. Effect of vibration on tolerances in composition of the fresh concrete, gradation of coarse aggregate, and maintaining line and grade of forms are factors in the development of adequate vibration equipment.

38. Vollick, C. A. EFFECTS OF VIBRATING CONCRETE. American Concrete Journal, Mar. 1958, pp. 721-732, Vol. 54. ACI Index, p. 352.

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 concents and different admixtures. Effect on bleeding and hardening time is also given.

39. Backstrom, James E. ORIGIN, EVOLUTION, AND EFFECTS OF AIR VOID SYSTEM IN CONCRETE. PART 3--INFLUENCE OF WATER-CEMENT RATIO AND COMPACTION. American Concrete Journal, Sept. 1958, pp. 359-376, Vol. 55. ACI Index, p. 358.

Size distribution, frequency of air voids, spacing factor, and freezing and thawing resistance of concrete are influenced by many factors, among the most significant being water-cement ratio and degree of compaction. Increased freezing and thawing resistance generally reflects a reduction in void size and spacing factor. Such reductions are obtained, other factors being equal, through reduced water-cement ratio, increased amount of air-entraining agent, and in the case of void size through increased periods of vibration. Reduction of water-cement ratio increases the proportion of air-entraining agent necessary to produce a given air content but the air content required for maximum durability is decreased as the water-cement ratio is decreased. Increasing periods of vibration reduce the total air content and increase the specific surface of air voids, but have relatively little effect on spacing factor. For any one concrete there is an optimum air content and void spacing factor for optimum resistance to freezing and thawing. Spacing factor which obtains at optimum freezing and thawing resistance of a single concrete variously vibrated may or may not be the smallest in magnitude.

40. Tyler, Raymond George. AN INTERPRETATION OF THE RESULTS FROM VIBRATING WIRE STRAIN GAGES IN FRESH CONCRETE. Road Research Laboratory, Berkshire, England. Presented at the Highway Research Board meeting, January 1968.

A program of tests concerning creep, shrinkage and temperature movements in highway bridges is being conducted by the Bridges Section of the Design Division of the Road Research Laboratory. The paper describes part of this work, namely, the interpretation of the readings from acoustic strain gages in fresh concrete, up to the time of heat of hydration is dissipated. The characteristics of the vibrating wire gage are described, together with the results of two laboratory experiments and three fullscale site investigations. The results show that usually expansions take place during the hydration of typical bridge concretes as used in the United Kingdom; these were manufactured from

normal portland cement having water/cement ratios in the range 0.38 to 0.40.
The paper also discusses the strain changes which occur on cooling during the dissipation of the heat of hydration in full-scale structures, and an instance of cracking caused by differential strains on cooling is described. The effect of the use of limestrne aggregate having a low coefficient expansion is shown by one of the investigations and it is demonstrated that cooling after hydration produces a self-straining set of forces within the concrete, the reinforcement being in tension to approximately 3500 psi, while the concrete is in compression.

41. Prasad, Mahabir and Tayal, J. C. THE EFFECTS OF REVIBRATION ON THE PROPERTIES OF CEMENT CONCRETE. Journal of the Indian Roads Congress (Jamnagar House, Shahjehan Rd., New Delhi II, India), Vol. 29, No. 4, pp. 651-661, Aug. 1966. HR Abstracts, March 1967.

Studies were made and tests conducted to determine effects on the properties of cement concrete by revibration at regular intervals up to four hours after placing. Laboratory tests were conducted on a 6-in. cube and 6- x 6- x 24-in. beam specimens cast with concrete of different water-cement ratios but with the same mix. The specimens were tested for compressive strength, flexural strength, and water absorption. Nondestructive testing with an ultrasonic apparatus and an impact hammer was also done. Field tests were conducted on 10½-ft long rectangular concrete beams, both plain and reinforced, having different water-cement ratios but the same mix. It was concluded that by revibration both compressive and flexural strengths were improved and water absorption was reduced.

42. Gemerling, G. V. and Chernov, A. N. VIBRATED FLY-ASH CONCRETE. Stroit. Materialy i Betony, Chelyabinsk, Sb. 1964, 83-7 (U.S.S.R.). Ref. Zh., Khim. 1964, 17M118. Chemical Abstracts, Vol. 62, No. 7, p. 7490, March 29, 1965. HR Abstracts, July 1965.

Experiments conducted to improve the technology of production of fly ash concrete from stiff mixes are described. Material consumption in kilograms per cubic meter of concrete was: cement, 250; electrical power station ash, 500; unslaked lime, 50; Al powder, 0.7; and water, 230, to 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 powder 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 hr. 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.

43. Weinland, S. L. and Weinland, L. A. A VIBRATION FLOW TEST FOR CEMENT MORTARS. Materials Research & Standards (1916 Race St., Philadelphia 3, Pa.), Vol. 4, No. 4, pp. 165-167, April 1964. HR Abstracts, 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. 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.

44. Mirsu, Ovidiu and Best, Cecil H. SOME OBSERVATIONS ON THE REVIBRATION OF CONCRETE AT DIFFERENT FREQUENCIES. Kansas Engineering Experiment Station, Special Rept. No. 45. Kansas State University (Manhattan, Kan.) Bull., Vol 48, No. 6, June 1964. 24 pp. HR Abstracts, March 1965.

The influence of amplitude and frequency of revibration at different times on the ultimate strength of high-strength concrete is considered. In particular, the effects 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 definitive work may be planned.

45. Subbotkin, M. I. and Trinker, B. D. EFFECT OF VIBRO-MIXING ON STRENGTH OF MORTAR AND CONCRETE. Trans. of Beton i Zhelezobeton (USSR), Vol. 8, No. 6, pp. 271-274, 1962. Technical Translations, Vol. 10, No. 7, p. 820, Oct. 15, 1963, Available from Office of Technical Services (Washington, D. C. 20230), 63-14714. $1.10. HR Abstracts, September 1964.

Tests carried out on various mortar and concrete mixes have demonstrated that the vibro-mixer developed by P. E. Mandrik and A. A. Shurygin guarantees better mixing of plastic and low-flowability mortar and concrete mixes than is possible in conventional mortar mixers. Vibro-mixing yields a definite effect also in mixing stiff mortar and concrete mixes which cannot be mixed or are difficult to mix in conventional mortar mixers.

The studies carried out have confirmed that vibro-mixing of mortar and concrete mixes is the most effective of all known methods, improves a number of properties, and increases and homogeneity of the mix, as well as the strength of mortar and concrete, particularly at early ages.

46. Kremer, P. VIBRATION TECHNIQUE IN MECHANICAL COMPACTION OF FRESHLY MIXED CONCRETE. Betonsteinztg (Kleine Wilhelmstrasse 7, Wiesbaden, Germany), 1963, 29 (4), 186-191. Building Science Abstracts, Vol. 36, No. 8, p. 226, Aug. 1963. HR Abstracts, July 1964.

Three features in the vibration of concrete are examined: (a) different particle sizes have their appropriate frequency; (b) with decrease of particle size higher frequencies are needed to achieve optimum compaction; and (c) the rate of vibration. A discussion on the relations between the physical properties of concretes and ease of vibration is followed by a description of methods of compaction and equipment. Although the most effective frequcncy cannot be determined, higher strengths are achieved if with higher w/c ratios the frequency is raised. Each mix must have a min. amplitude assigned to it for complete compaction. The lower the w/c ratio, the greater the acceleration needed to over come the internal friction of the mix.

47. Green H. and Roberts, A. B. A NOTE ON THE EFFECT OF FREQUENCY ON THE BEHAVIOUR OF FRESH CONCRETE DURING VIBRATION. Magazine of Concrete Research (52 Grosvenor Gardens, London, S. W. 1), Vol. 15, No. 44, pp. 115-117, July 1963. HR Abstracts, May 1964.

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.

48. Green, Harry. THE EFFECTS OF AGGREGATE GRADING AND VIBRATION FREQUENCY ON THE COMPACTION OF CONCRETE BY TABLE VIBRATION. Proc., Institute of Civil Engineers (Great George St., London, S. W. 1), Vol. 22, Paper No. 6603, pp. 377-390, August 1962. HR Abstracts, June 1963.

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 linear vibration has been applied and extraneous influences have been reudced 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 aggregates were compacted 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 larger maximum size. The mixes were vibrated in 4-in. cube molds at eight frequencies ranging from 25 to 230 cycles per sec, (1,500 to 13,800 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 mean particle size was increased.

49. Green H. THE COMPACTION OF MORTAR AND CONCRETE BY VIBRATION. 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. 622-634, May 1962. HR Abstracts, Jan. 19

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.

50. Birger, A. and Klopovskii, A. PREFABRICATED ROADS MADE FROM VIBRA-ROLLED CONCRETE SLABS. Stroitel-stvo I Arkhitektura, Moskvy (Moscow, USSR), 1961, 10 (3) 13-5. (In Russian). Road Abstracts, Vol. 29, No. 5, p. 108, May 1962, HR Abstracts, January 1963.

Precast concrete slabs measuring 3.5 m by 2.5 m by 0.16 m were used for two experimental road projects in the USSR. Each slab is reinforced on the underside by reinforced concrete ribs forming a grid pattern; a metal die is used to mark the pattern on the 30-cm thick sand base before the concrete slab is placed in position. The slabs were assembled by crane on the base and were filled with sand and the road was opened to traffic. The slabs in the experimental sections for heavy traffic had more reinforcement and weighed more than the slabs for the other section, but otherwise they were the same. Both types have so far proved durable under traffic. (Note: an abbreviated English version of this article appears in Tech. Dig., Praha, 1962, 4 (4), 44-5.

51. Wlaz, Kurt. DETERMINATION OF THE CONSISTENCY OF CONCRETE BY THE COMPACTING RATIO METHOD. Forschungsinstitut der Zementindustrie, Dusseldorf, West Germany, Presented at the Highway Research Board meeting, January 1968.

The bulk density of a loosely charged concrete is dependent on its consistency. The relation of the volume of a loosely charged batch of concrete to the solid volume of this batch (for example after complete compaction) represents as "compacting factor" a simple rate for the consistency.

For this procedure essentially a presmatic container and any tool for compaction are only necessary (vibrator or tamper). By this method the consistency of concrete with any maximum size of aggregate can be measured in the range from pulpy to stiff. For this the "compacting factor" extends from about 1.05 to about 1.50.

52. Plowman, J. M. THE INFLUENCE OF VARIABLES IN THE VIBRATION OF CONCRETE. Concr. Build. Concr. Products, 1953, 28 (9), 205-7. Road Abstracts (London), Vol. 21, No. 2, p. 26, February, 1954. HR 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.

53. Kirkham, R. H. H. DESIGN OF CONCRETE MIXES FOR COMPACTION BY SURFACE VIBRATORS. Symposium on Mix Design and Quality Control of Concrete, London, May 11-13, 1954. HR Abstracts, September 1954.

The design of a mix suitable for compaction by vibration in a concrete road differs only from that for other structures because of the small variations in strength and workability which can be accepted. Generally 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 economical 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, a laboratory test is required for assessing the suitability of a mix for 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 more efficient compacting machines. It would be necessary, however, for some to be made in the form of the specifications.

54. Plowman, J. M. BOND IN VIBRATED CONCRETE. Civ. Engng., Lond., 1954, 49 (582) 1293-5. Building Science Abstracts (England), Vol. 28, No. 4, p. 103, April 1955. HR Abstracts, July 1955.

The bond tests and researches described were made to determine the influence of (1) congestion of bars, (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 tested, 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.

55. CONCRETE MIX DESIGN FOR VIBRATION. Highways and Bridges and Engineering Works (Crescent House, Ashford, Middlesex, England), Vol. 23, No. 1131, pp. 6, 8, March 21, 1956. HR 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 admirable 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 a 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, one hears that the vibration has been too long and that the mortar has been drawn to the vibrator, whereas in fact it is usually the grading or the mix that is at fault. Research 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 (in 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 experience of the unstable mixes it became apparent that there were three types of 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 of 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) The more rounded the aggregate the harsher the grading limit to the unstable zone. (3) Gap gradings have lower limit curves than continuous gradings and a larger zone of instability. (4) Increase of acceleration with differential acceleration will lower the lower instability limit. (5) The worst cases of instability occur with mixes approximately 1:5 and water-to-cement ratios of approximately 0.4.

56. COMPACTION BY VIBRATION. Western Construction, Vol. 30, No. 12, p. 42, December 1955. HR 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 product 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 rmp. 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 surpassed. 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 passes 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 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 in 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 fill, and the backfulling of trenches.

57. Williams, T. E. H. GAP-GRADED AGGREGATES IN VIBRATED CONCRETE. Engineering (London), Vol. 179, No. 4662, pp. 693-698, 1955. Building Science Abstracts, Vol. 28, No. 11, p. 322, November 1955. HR 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 concrete are established. The criterion for 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 calculating 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 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.

58. REPORT ON VIBRATED CONCRETE. Highways and Bridges and Engineering Works (Crescent House, Ashford, Middlesex, England), Vol. 24, No. 1155, p. 4, September 1956. HR Abstracts, February 1957.

The report on "The Vibration of Concrete" prepared by the Joint Committee of the Institution of Civil Engineers (Great George St., Westminster, London S.W. 1) and the Institution of Structural Engineers (147 Victoria St., London, S.W. 1), has been published in the form of a fully illustrated booklet.

The Committee makes 11 points for a draft specification for vibrated concrete additional to the clauses of a normal specification, and calls for further research on seven points as foloows:

1. It is essential that the vibrations of particles should be maasured. This can be done by the method devised and advocated by Whiffin, Morris and Smith. This has been carried far in the Road Research Laboratory, especially in connection with surface vibrators. To the Committee's knowledge no such systematic research has been carried out in other types of vibration.

2. There is still doubt as to the best proportions of immersion vibrators, such as the ratio of length to diameter, etc.

3. The development of a simply applied test apparatus for determining the workability of the concrete in the mixer or as it leaves the mixer is required.

4. Design of mixes for vibrated concrete in relation to the tensile and crushing strengths, elastic modulus, bond, permeability, shrinkage and creep, especially for lean and gap-graded concretes.

5. The best type of mixer for dry concretes as used for vibrated work.
6. The wave-form and direction of vibration and the best frequencies and amplitudes with all types of vibrators.
7. The best methods of placing the concrete in various types of structure and the best positions of vibrators.

59. Vollick, C. A. EFFECTS OF REVIBRATING CONCRETE. Journal of the American Concrete Institute (P. O. Box 4754 Redford Station, Detroit 19, Mich.), Vol. 29, No. 9; Proceedings, Vol. 54, pp. 721-732, March 1958. HR Abstracts, June 1958.

Tests were made to determine the effect of revibration at intervals of 1 to 4 hr after placing on properties of hardendd 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 proporly 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 after 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 hr.

Revibrated 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 bottom of 24-in. block.

Appearance of concrete can be improved by revibration.

The delay between placement and revibration of concrete can be increased if a set retarder is added to the concrete.

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.

60. Kolek, J. THE EXTERNAL VIBRATION OF CONCRETE. Civil Engineering and Public Works Review (8 Buckingham St., London, W. C. 2), Vol. 54, No. 633, pp. 321-325, March 1959. HR Abstracts, June 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.

61. Pilny, F. MEASURING THE STIFFNESS AND THE VIBRATING CAPACITY OF FRESHLY-MIXED CONCRETE. Bauingerieur (Springer-Verlag, Reichpietschufur 20, Berlin, W 35), Vol. 33, No. 5, pp. 169-174, 1958. Building Science Abstracts, Vol. 31, No. 8, p. 231, August 1958. HR Abstracts, July 1959.

Equipment is already available for testing the stiffness and the vibrating capacity (the workability) of freshly-mixed concrete, and tests of these properties yield sufficient information for assessing conclusively the compressive strength of concrete. This test procedure has the advantage over existing methods (calculations based on the water/cement ratio or the particle-size distribution) that the strength properties are estimated from the finished product, and no laborious calculation of constants is required. Such empirical methods are justified where local conditions make it imperative to have a direct estimate of the general properties of concrete.

62. Blandin, F. H. and Larsen, O. EFFECT OF INTERNAL VIBRATION OF CONCRETE MIXTURES UPON THE ENTRAINED AIR. Illinois Highway Engineer (Illinois Association of Highway Engineers, 209 Jefferson Ave., Elgin, Ill.), Vol. 11, No. 2, 2nd Quarter, pp. 2-4, 10, 1959. HR Abstracts, November 1959.

In accordance with the requirements 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. 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. 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 of 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 at 200 cycles, and 60 at 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 undoubtedly are of sufficient interest to warrant further investigation.

63. Giuliana, Grancisco and Sobledo, Paul S. INFLUENCE OF PARTICLE-SIZE DISTRIBUTION ON STRENGTH AND WORKABILITY OF VIBRATED MORTAR. Materials Research & Standards (American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.), Vol. 1, No. 3, pp. 183-188, March 1961. HR Abstracts, June 1961.

These tests show that, in the grading of sand, an improvement over the fineness modulus is the scheme of using two "normal sieve openings," which, in the grading curve, correspond to the finer 10 and 60 percent, according to Allen Hazen's definitions and extensive use in permeability and soil classification. The name of "effective sizes" may be properly generalized because of the influence of these nominal sieve openings on the permeability of sands and on the properties of concrete.

Use of a chart with these effective sizes as coordinates of grading is proved to be an efficient way to represent each measurable property of the concrete with respect to the grading of sand.

64. Green, H. EFFECTS OF AGGREGATE GRADING AND VIBRATION FREQUENCY ON COMPACTION OF CONCRETE BY TABLE VIBRATION. Instn Civ Engrs--Proc v 22 Aug 1962 p 377-90.

When mortar mixes made with graded aggregates were compacted by vibration, mixes with aggregates containing majority of large particles had higher optimum frequencies than mixes with small particles; investigation to determine whether same phenomenon applies to concrete mixes made with graded aggregates of larger maximum size; for each concrete mix, it was found that one frequency produced best compaction as judged by compressive strength; this frequency increased as proportion of sand in mix was decreased.

65. Green, H. COMPACTION OF MORTAR AND CONCRETE BY VIBRATION. Civ Eng (Lond) v 57 n 669, 670 Apr 1962 p 467-9, May 632-4.

Vertical linear vibration was applied at frequencies from 35 to 245 cps to mixes of cement and single-sized aggregates in range of size up to 3/8 in. and

of cement and combinations of these aggregate sizes; rich and lean mixes with 3 water contents were tested for each combination of aggregates; results show that frequency for which maximum strength is obtained (optimum frequency) is influenced by particle size of aggregates and tends to increase as size of particle is increased.

66. Kremer, P. and Schulz, H. E. UNTERSUCHUNG DER SCHWINGUNGSPROBLEME BEI DER MASCHINELLEN VERDICHTUNG VON FRISCHBETON. VDI Zeit v 104 n 9 Mar 21 1962 p 397-402.

Study of vibration problems in mechanical compacting of concrete; nonporous concrete whose component parts are of approximately equal strength, can be obtained by mechanical compaction provided that vibrating process is taken into account in composition of freshly mixed concrete; internal and external vibrators; application of concrete vibrating equipment.

67. Sneddon, W. K. NOTES ON VIBRATING TABLES. Constructional Rev v 29 n 6 June 1956 p 18-21, 38.

Vibrating table provides most consistent method of applying vibrations for compacting concrete, and correlation of actual performances and predicting performances by calculation should be mu h simpler than with other methods; application of theory of dynamics to problem, indicating uses and limitations of such approach; application of analytical findings to practice.

68. Plowman, J. M. RECENT RESEARCH ON VIBRATION OF CONCRETE. Reinforced Concrete Rev v 4 n 3 Sept 1956 p 177-202 (discussion) 202-20.

Regulations relating to bond stress and anchorage lengths in light of fresh experimental evidence; mix design for vibration; propagation of vibration inside concrete; measurement of vibration in concrete.

69. Poucher, M. P. COMPACTION AND FLOW OF CONCRETE. Mag Concrete Research v 6 n 18 Dec 1954 p 139-48.

Tests for comparison between workability and mobility of concrete mixes suitable for compaction by vibration; variations in mix design for high quality concretes are discussed stress being placed on concrete containing high proportion of maximum sized aggregate; combined workability and mobility measurements.

70. Barrett, C. R. FROM SHIPS TO BRIDGES--REVIBRATION PUTS MORE LIFE IN CONCRETE. Eng News-Rec v 154 n 10 Mar 10 1955 p 42-4.

Revibration makes denser concrete, produces tenacious bond, removes air and water pockets, prevents honeycomb, releases water trapped beneath horizontal reinforcing bars, and reduces or eliminates surface irregularities; example of Tappan Zee Bridge, largest single structure on New York Thruway.

71. Williams, T. E. GAP-GRADED AGGREGATES IN VIBRATED CONCRETE. Engineering v 179 n 4662 June 3 1955 p 693-8.

Studies of relationships governing particle interference and establishment of principle governing action of gap graded aggregates in vibrated concrete.

72. Plowman, J. M. EFFECTIVENESS OF VIBRATION OF CONCRETE. Engineer v 197 n 5118 Feb 26 1954 p 302-3.

Investigation into effectiveness of compaction achieved with vibrating table; accelerometers were embedded in concrete and acceleration contours for various specimens obtained.

73. Plowman, J. M. WORKABILITY OF VIBRATED CONCRETE. Mag Concrete Research n 15 Mar 1954 p 127-30.

Method of comparing workability of mixes of low water content by measuring power required to vibrate them under standard conditions; example illustrates use of relationship between number of gaps in grading and average power demand in calculating weight of concrete which can be vibrated under given conditions.

74. Bergstrom, S. G. LABORATORY TESTS ON VIBRATION OF CONCRETE. Am Concrete Inst--J v 24 n 10 June 1953 p 893-908.

Survey of tests dealing with pressures, displacements, and energy consumption in fresh concrete compacted by internal vibration; three methods of determining radius of action of internal vibrator; data on energy consumption during vibration; relation between properties of hardened concrete and time of vibration.

75. Tuthill, L. H. VIBRATION OF MASS CONCRETE. Am Concrete Inst--J v 24 n 10 June 1953 p 921-31.

Development of vibrating concrete during past 20 years; efficient use of vibration; amount and adequacy of vibration; effect on air entrainment; depth of layer to vibrate.

76. Washa, G. W. VIBRATION PRACTICES IN PIPE, PRECAST, AND BLOCK MANUFACTURE. Am Concrete Inst--J v 24 n 10 June 1953 p 945-52.

General discussion confined to statement regarding present practices; no attempt has been made to indicate superiority of one method or process over another.

77. Banker, J. H. VIBRATION PRACTICES IN STRUCTURAL WORK. Am Concrete Inst--J v 24 n 10 June 1953 p 953-6.

Operation of concrete vibrators in field; placing and vibrating concrete in walls is given special emphasis.

78. Williams, T. E. H. VIBRATORY METHODS OF COMPACTION AS AID TO CONTROL OF CONCRETE QUALITY. Instn Mun Engrs--J v 79 n 7 Jan 1953 p 346-51.

Types of vibrators such as pneumatic shutter vibrator, vibrating tables, plate vibrator and screed vibrator; compaction and crushnng strength variation depending on vibration.

79. Larnach, W. J. CHANGES IN BOND STRENGTH CAUSED BY RE-VIBRATION OF CONCRETE AND VIBRATION OF REINFORCEMENT. Mag Concrete Research n 10 July 1952 p 17-21.

Effects of revibration of partially set reinforced concrete; application of vibration directly to reinforcement during concrete placement; tests indicate that high values of unit bond strength can be attained by vibrated concrete; maximum reduction in bond strength occurred when concrete with small water-cement ratio was revibrated after period of three hours from casting.

80. Kirkham, R. H. H. and Whiffin, A. C. EXPERIMENTS ON VIBRATION OF FRESHLY PLACED CONCRETE. Engineer v 193 n 5012 Feb 15 1952 p 240-3.

Beams for vibrating concrete road or runway slabs have been largely developed empirically; machine designed by Road Rssearch Laboratory to study effects of variables involved; tests on effects of amplitude of vibration, number of vibrations in given length, acceleration of beam, and of work done by compacting machine; practical implications; illustrations.

81. Venkatramaiah, S. MEASUREMENT OF WORK DONE IN COMPACTING KNOWN WEIGHT OF CONCRETE BY VIBRATION. Mag Concrete Research n 5 Jan 1951 p 89-96.

Compaction done by electric vibrator; tests carried out so that estimates of electrical and frictional losses could be made, thereby enabling net work done in compacting concrete to be calculated; results of compacting factor tests made on same concretes.

82. Davies, R. D. SOME EXPERIMENTS ON COMPACTION OF CONCRETE BY VIBRATION. Mag Concrete Research n 8 Dec 1951 p 7108.

Cubes of very dry concrete, of mix proportions suitable for small prestressed beams, were compacted by vibration of various types, frequencies and amplitudes; crushing strengths obtained are analyzed statistically.

83. Stewart, D. A. VIBRATED CONCRETE. Civ Eng (Lond) v 47 n 555, 556 Sept 1952 p 745-7, Oct p 835-8; see also Water Power v 4 n 11 Nov 1952 p 420-3.

Recent developments in concrete technology with particular references to aggregate sizes and specific bulk density.

84. Whiffin, A. C. and Morris, S. A. and Smith, R. T. MEASUREMENT OF VIBRATIONS IN FRESHLY PLACED CONCRETE. Mag Concrete Research n 4 July 1950 p 39-46.

Electronic apparatus developed at Road Research Laboratory for measuring vibrations; circuits, calibration arrangements, and type of information obtainable; piezoelectric accelerometers, used with cathode ray tube equipment, give photographic records of acceleration at various depths of concrete; reference to paper by R. H. H. Kirkhain, indexed in Engineering Index 1950 p 1019 from December 1949 issue; diagrams.

85. SHOCK CONCRETE. Indian Concrete J v 25 n 5 May 1951 p 92-6.

Method of manufacture and data on properties such as weight, strength and permeability; illustrated examples of structures made of vibrated concrete.

86. Stewart, D. A. VIBRATED CONCRETE. Reinforced Concrete Rev v 2 n 5 Jan 1951 p 277-306 (discussion 306-14.)

Relation of frequency, acceleration and amplitude to one another represented by fundamental equation; methods adopted in producing vibrations described; types of vibrators; comparison of hand filled and vibration filled aggregates.

87. Fritsch, J. VIBRATED MASS CONCRETE. Civ Eng (Lond) v 46 n 535 Jan 1951 p 30-2, Feb p 102-4.

Survey of errors in present practice of making mass concrete; principles of concrete strength; production of mass concrete with uniform properties; determination of properties of freshly placed concrete; grading of aggregates in lean concrete; impermeable concrete.

88. Jellick, J. E. VIBRATION FOR QUALITY CONCRETE. Architect &Engr v 182 n 1 July 1950 p 9-11.

Illustrated examples of vibration of concrete; benefits of placing concrete by vibration; data on equipment and consistency; effects of water cement ratio; strength and economy; proportioning concrete for vibration.

89. Kolek, J. INTERNAL VIBRATION OF CONCRETE. Civ Eng (Lond) v 54 n 640 Nov 1959 p 1286-90.

Tests on internal vibrators suitable for use in precast concrete industry test method is based on determination of ultrasonic pulse velocity in block of concrete compacted by internal vibration; 10 different vibrators have been tested in this way.

90. Mattison, E. N. SOME EXPERIMENTS WITH DELAYED AND REPEATED VIBRATION OF CONCRETE. Constructional Rev v 32 n 9 Sept 1959 p 29-33.

Vibration after concrete has stood in place for 3 hr improves compressive and tensile strengths and surface finish; this treatment is "delayed vibration" when initial compaction has been by rodding alone or "repeated vibration" when earlier vibration was used for initial compaction; higher cement contents showed lower strength increases; graphs show relationship between maximum bleeding and repeated vibration.

91. Mironov, S. A. SPOSOBY POLUCHENIYA VYSOKOPROCHNYKH BETONOV DLYA VIBROPROKATA PRI KRATKOVREMENNOI TEPLOVOI OBRABOTKE. Beton i Zhelezobeton v 5 n 1 Jan 1959 p 4-10.

Method of fabrication of high strength concrete subjected to vibratory rolling during short time thermal treatment; various types of Soviet concrete are tested to determine conditions and possibility of manufacturing thin-walled and reinforced panels by means of vibratory rolling.

92. Kokek, J. ESTERNAL VIBRATION OF CONCRETE. Civ Eng (Lond) v 54 n 633 Mar 1959 p 321, 323-5.

Influence of acceleration, amplitude and frequency of vibrations; generalized theory of compaction is suggested; practical recommendations are quoted for external vibration; estimation of type and number of vibrators needed; relation between rated power and centrifugal force in various makes of rotating eccentric type external vibrators.

93. Branberger, K. TECHNIQUE IN BUILDING. Czelchoslavak Heavy Industry n 11 1958 p 10-14.

Types of immersion and surface vibrators produced in Czechoslovakia for use in different branches of building industry; large vibro-pressing machines for production of large size precast elements of plate character now developed; two types of vibration mills produced, one of which is laboratory type, and other for continuous industrial production.

94. Farrar, N. S. VIBRATION WAVES IN CONCRETE. Engineer v 206 n 5354 Sept 5 1958 p 378-80.

Supplementing author's previous work (see Engineering Index 1957 p 229) further work is carried out with reference to table vibration in both theoretical and practical aspects of vibration as it affects concrete compaction.

95. Vollick, C. A. EFFECTS OF REVIBRATING CONCRETE. Am Concrete Inst--J v 29 n 9 Mar 1958 p 721-32.

Tests to determine 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 also given.

96. Cusens, A. R. INFLUENCE OF AMPLITUDE AND FREQUENCY IN COMPACTION OF CONCRETE BY TABLE VIBRATION. Mag Concrete Research v 10 n 29 Aug 1958 p 79-86.

Paper describes experimental work; cases of castings of small depth and those of greater depth are separated and guiding principles suggested for each; effects of rotational instability and influence of mold are considered; apparatus is described and graphs of tests results given.

97. Plowman, J. M. COMPACTION OF CONCRETE BY VIBRATION. Engineer v 203 n 5288 May 31 1957 p 830-2.

Supplementing article indexed in Engineering Index 1954 p 225, from Feb 26 1954 issue, account is given of further work carried out both with table and shutter vibrators, and with poker vibrators.

98. Peltier, R. NOTE SUR LA "REVIBRATION" DES BETONS. Annales des Ponts et Chaussees v 126 n 6-Nov-Dec 1956 p 811-9.

Study on effect of revibration on strength of concrete; test results confirmed those obtained previously by Dutron, in Belgium, namely that revibration of wet concrete is not dangerous as long as setting has not begun; revibration of dry concrete found to be very dangerous.

99. Doney, C. J. VIBRATION OF CONCRETE. Constructional Rev v 30 n 9 Sept 1957 p 18-24.

Advantages, principles and effect of vibration reviewed; characteristics of vibrators; method of working with internal vibrators; external and surface vibrators.