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COOPERATIVE
RESEARCH

PROPERTIES OF LIGHTWEIGHT CONCRETE

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in cooperation with the
Department of Commerce
Bureau of Public Roads

BIBLIOGRAPHY 67-2
SURVEY OF LIBRARY FACILITIES PROJECT

PROPERTIES OF LIGHTWEIGHT CONCRETE

1. Field practice in lightweight concrete, J. A. Murlin, C. Wilson. Am Concrete Inst--J 24: n 1, Sept 1952, p 21-36.

   Properties of expanded shale and clay aggregates produced in Texas; economy of light weight structural concrete members as compared to heavy concrete; design and control of light weight structural concrete, both ready and job mexed; methods of mixing, placing finishing and use of admixtures; economy of expanded clay or shale structural concrete.

2. Lightweight aggregate concrete, R. W. Kluge, M. M. Sparks and E. C. Tuma. Am Concrete Inst--J 20: n 9, May 1949, p 625-42, (discussion) v 21: n 4, pt 2, Dec p 644 (4p); see also Ice and Refrig 117: n 3 Sept 1949, p 24-6.

   Studies made by Nat Bureau of Standards; aggregates studied were expanded clay, shale and slate, expanded blast furnace slag, expanded vermiculite and perlite, sintered diatomite, fly ash and pumice; test results summarized.

3. Properties of some lightweight-aggregate concretes with and without air-entraining admixture, P. H. Petersen. U. S. Bur Standards--Bldg Matls & Structures--Report BMS112, Aug 16, 1948, 7 p, 10¢; see also Am Concrete Inst--J 20: n2, Oct 1948, p 165-75.

   Aggregates made with burned shale or expanded slag; three grades of concrete using each aggregate were made; air entrainment of greater than 20% is reported for mixtures leanest in cement; compressive, transverse, and bond strengths; coefficients of thermal expansion, shrinkage, and values for change in length due to wetting and drying.

4. Use of fly ash in concrete pavement constructed in Nebraska, Charles A. Sutton. Nat'l Research Council--Highway Research Board Abstracts 33: n 12, December 1963, p 55-56.

   Nebraska has an abundance of sand-gravel in streams and old lake beds that in many ways is an excellent aggregate for use in concrete. It provides a concrete that is highly workable in the plastic stage and durable with high strength after it hardens. However, certain materials in this aggregate often react with portland cements in such a manner that disruptive expansion is produced in concrete and its useful life is considerably reduced.

Various methods for inhibibiting this reaction and its resulting expansion have been investigated and one method that was to use fly ash in the concrete. Since the laboratory test were favorable, two experimental test roads, each approximately six miles in length, were constructed with concrete involving the use of fly ash. One road was constructed in 1950, the other in 1951.

This is a report of the data accumulated from these test roads, which indicate that the use of fly ash in the concrete presented no special problems in construction and the fly ash concrete was durable, high in strength, and did not expand because of cement aggregate reaction.

5. Experimental fly ash concrete pavement in Michigan, F. E. Legg, Jr., Nat'l Research Council--Highway Research Board Abstracts 33: n 12, December 1963, p 56.

   The Michigan experimental fly ash concrete pavement was constructed in 1955 and is 1,750 feet long. It may be of interest primarily for two reasons: (1) Five sections are included in the project with ash contents varying from none to 200 lb. per cubic yard. Simultaneously, cement content was varied in increments from 5.5 to 4.0 sacs per cubic yard, and (2) loss on ignition of the fly ash was high (13 to 14 percent) requiring very large amounts of air-entraining admixtures to maintain the air content at levels considered necessary for satisfactory resistance to severe weather conditions and de-icing salts. Compression and flexural strength test specimens are made from the job concrete from each section and strengths are reported at ages up to 5 years. Strengths of drilled cores are also reported along with accelerated scaling tests on job-made slabs. Observations at the age of eight years do not indicate positive superiority of behavior of any of the test sections and the present paper will have to be considered a combined construction and progress report.

6. Concrete containing fly ash as a replacement for Portland blastfurnace slag cement, W. E. Grieb and D. O. Woolf. Proc Amer Soc Test Mater 61: 1961, p 1143-53; Discussion 1154.

   Investigations by the Bureau of Public Roads have shown that fly-ash can be used satisfactorily to replace part of the cement but the properties of the concrete are affected by the carbon content of the fly-ash, lower strengths being associated with higher carbon contents. The amount of the fly-ash used should be more than about 15 percent by weight of the CaO content of the cement.

7. The estimation of the strength of concrete made with lightweight aggregate, K. Shirayama.
Mag Concr Res 13: n 38, 1961, p 61-70.

The results of compressive strength tests carried out on concrete made with Laca expanded clay aggregates, produced in Norway, showed good aggrement with an empirical formula. The relations between cube strength and cylinder strength and modulus of elasticity are discussed. A table of proposed mix proportions is given.

8. Determining the suitability of clays for the production of lightweight aggregates, V. S. Ramachandran, N. C. Majumdar and N. K. Patwardhau.
Indian Concr J 35: n 12, 1961, p 453-6.
This article discusses how an understanding of certain physico-chemical processes involved in the bloating of clays will be helpful in predicting the bloating properties of a clay by simple and reliable methods for subsequent pilot plant studies. A bibliography of 15 references is appended.

9. Studies relating to the testing of fly ash for use in concrete R. H. Brink and W. J. Halstead.
Publ. Rds. Wash 29: n 6, 1957, p 121-141.

This paper, which was presented at the 59th Annual Meeting of the American Society for Testing Materials, 1956, gives the result of an investigation carried out by the Physical Research Branch of the U. S. Bureau of Public Roads. The study was concerned mainly with the pozzolanic behaviour of fly-ash and of its effectiveness in reducing the expansion which results from the alkali-aggregate reaction. Lime and sodium hydroxide were shown to be unsatisfactory reagents for estimating the pozzolanic activity of fly-ash, but it is thought that a suitable lime-fly-ash mortar test might be developed after further study: 34 samples from 19 different sources were examined. It was found that: (1) The effect on mortar strength of replacing part of the cement with fly-ash varies with the cement used. (2) Fly-ash has the greatest proportional benefit on the ultimate strength of lean mixes, although tests at 28 days do not usually indicate this. (3) The carbon content of fly-ash lowers the strength of mortar because it increases the amount of water required to obtain a workable consistency (4) Finer fly-ashes produce higher strength in mortars: The strength was shown to be related to the amount of fly-ash passing a No. 325 sieva, but not to the specific area of the fly-ash as determined by the air permeability method. (5) If the addition of fly-ash requires an increase in the amount of water needed to prepare mortar of a stated consistency, the strength of the mortar decreases. (6) Fly-ash inhibits the volume change caused by the alkali-aggregate reaction if used in sufficient amount. The testing procedures are given in an appendix.

10. Use of fly ash in concrete, A. G. Timms and W. E. Grieb. Publ. Rds. Wash 29: n 6, 1957, p 142-50.

The properties of concrete containing 4 types of fly-ash were examined by the Physical Research Branch of the U. S. Bureau of Public Roads. Flexural and compressive concrete without fly-ash, but at one year the fly-ash concrete was at least as strong as comparable normal concrete. Fly-ash did not affect resistance to freezing and thawing of normal concrete. In air-entrained concrete, some fly-ash gave satisfactory durability but others did not. Concretes containing higher percentages of fly-ash generally had less shrinkage than those with smaller ones. Any substitution of fly-ash for Portland cement lowered the resistance of the concrete against attack by calcium chloride. The amount of air-entraining material necessary to produce a given amount of air in concrete is said to increase with the carbon content of the fly-ash. This paper was presented at the 59th Annual Meeting of the American Society for Testing Materials, 1956.

11. The use of blast-furnace slag as a concrete aggregate, E. F. Farrington. Proc Instn Civ-Engrs. Part I. 5: n 1, 1956, p 56-9.

Molten slag from blast furnaces producing basic iron is tipped into shallow pits to cool and harden. It is then dug up and processed to conform to B. S. 1047: 1952. Uses of slag in plain or reinforced concrete construction are described. Some characteristics of the aggregate and of the concrete obtained are discussed. It is suggested that slag which conforms to the British Standard should be considered on equal terms with other aggregates.

12. Studies on the suitability of expanded shale aggregate for use in cement concrete, D. H. Sawyer, C. M. Brown and L. H. Strunk. University of Kentucky, Engineering Experiment Station Bulletin 38: Lexington, Kentucky, 1955 28 p.

The main purpose of this investigation was the evaluation of the physical and structural characteristics of concrete made with expanded shale aggregate in order to determine its potential uses in bridge decks. It was found that concrete mixes containing expanded shale can have: (1) Compressive strengths approximately equal to and flexural strengths slightly lower than those of comparable mixes containing dense aggregate. (2) A satisfactory bond with reinforcing steel up to the yield point of the steel, even though the relation between slip and bond stress is somewhat less favorable for the light-aggregate concrete than for comparable dense concrete. (3) An extremely poor resistance to freezing and thawing carried out normally in durability testing. (4) An inherent resistance to resaturation after being dried. (5) An increase in resistance to freezing and thawing by the use of air entrainment. (6) A high resistance to abrasion when measured by a modified Los Angeles,type test. (7) Unit weighs approximately 35 percent less than those for corresponding mixes containing limestone aggregate.

13. Fly ash concrete for highways in Kansas, W. M. Stingley and R. L. Peyton.
Nat'l Research Council--Highway Research Board Abstracts 33: n 12, December 1963, p 56.

Although fly ash has been widely used as an admixture in mass concrete, its use in concrete highway construction has been limited. It has been used in Kansas, as a replacement for an part of the cement, in one experimental paving project that has been under traffic for 14 years. Five brands of cement with a single aggregate and fly ash from a single source. Although this project has been reported previously, no detailed study of the fly ash sections,which included varying results with change in cement brand, was made.

Evaluation of effectiveness in preventing map cracking is based on the supposition that reductions in flexural strength accurately reflect increases in map cracking as here defined. Other variables, such as changing moisture content, are given consideration,but are assumed to balance out over a long period.

14. Influence of various factors on sulfate resistance of concretes containing pozzolan, M. Polivka and E. H. Brown.
Proc Amer Soc Test Mater 58: 1958, p 1077-99: Discussion 1099-1100.

An investigation has been carried out at the University of California on the effects of several types of exposure and curing period on the sulphate resistance of concretes containing cements of high and very low pozzolan replacements. It is concluded that: (1) a pozzolan of high quality used as a partial replacement of high C_3A cement will greatly improve sulphate resistance. (2) The use of a very low C_3A cement results in concretes with superior resistance to sulphate action. A partial replacement of this cement with pozzolan does not improve sulphate resistance. (3) Curing for more than 28 days has no appreciable effect in improving resistance of concretes to the action of a mixture of sodium and magnesium sulphate solution. (4) Continous complete immersion of concrete specimens in sulphate solutions appears to be a satisfactory method for laboratory investigations. (5) A mixture of sodium-magnesium sulphate attacks the exposed concrete surface, causing surface scaling, while sodium sulphate alone tends to penetrate into the concrete, causing swelling and cracking without scaling of the exposed surface. (6) The loss-in-weight method seems to provide the most positive evaluation of potential sulphate resistance. Twelve literature references are appended.

15. Some statistical analysis of the strength and durability of fly ash concrete, T. J. Pasko and T. D. Larson. Proc Amer Soc Test Mater 62: 1962, p 1054-67.

A systematic method is presented for determining the amount of fly ash needed to produce concrete with optimum strength and durability. An experimental factorial design was used to analyse statistically the effectiveness of a typical commercial fly ash as a partial substitute for cement in a road paving mixture. Concrete specimens made from various mixtures were tested for strength and freezing-and-thawing durability. The results of flexural and compressive strength tests showed that maximum strength was obtained when 120 lb of cement was replaced by 147 lb. of fly ash per cubic yard of concrete.

16. Concrete with slag aggregate, Association Technique Pour Le Development Des Utilisations Des Laitiers De Hauts Fourneaux. Laitiers & Tarmacadam 12: n 11, 1958, p 51-60 (In French).

A review is given of current methods of using fly ash which eliminate the need for paying for its disposal from electricity generating stations. About 3½ million tons, expected to rise to 4 million tons by 1961-62, are dealt with annually in the United Kingdom. Consideration is given to the properties of fly ash and its applications as bulk fill, as an admixture of concrete, in soil stabilization as a filler in asphalt, as a binding material to fill aggregate voids in road base construction, and as a sintered aggregate.

17. The use of pozzuolanic materials in mortars and concretes, C. K. Murthy, Indian Concr J 31: n 6, 1957, 186-90.

This review summarizes the properties of pozzolanic materials, including chemical composition of 18 types, and discusses the theory of pozzolanic action. The use of pozzolans as replacement for some of the Portland cement in concrete increases the plasticity of fresh concrete and reduces the tendency to bleeding and segregation, the effect being greater in lean mixes than in rich ones; the extent of the improvement is affected by the type, fineness and amount of the pozzolan. Pozzolanic materials reduce the permeability of lean-mix concrete, counteract expansion due to alkali-aggregate reaction, increase volume changes which accompany changes in moisture content, may reduce creep, may improve resistance to sulphate water, and reduce heat of hydration.

18. Sydney Fly Ash in Concrete, G. B. Welch and J. R. Burton. Commonw. Engr. 45: n 5, 1957, p 48-53; 1958, n 6, p 62-7.

A laboratory investigation is described on the effects of a limited number of typical examples of Sydney fly-ash on the properties of concrete mixes. It was found that it is successfully in concrete as a cement replacement or as an admixture.

19. Surkhi as a puzzolane, N. R. Strinivasan. Central Road Research Institute, Road Research Paper No. 1, Delhi, 1956 (Central Road Research Institute), 74 p.

An investigation into the use of surkhi (burnt clay) as a pozzolan was carried out in two parts. In the first part, a study was made of the mineralogical and crystallographic characteristics of five clays and the surkhis derived from them, a shale, a clay stone and an unknown soil. In the second part, a large number of soil samples was studied, work being concerned mainly with the preparation of surkhis at different temperatures and finding their reactivities by the lime reactivity test. As a result of the investigations, it is concluded that loamy soil which are generally used for making bricks do not yield surkhi but the reactivity depends largely on the type of clayminerals present and the degree of burning. Before using any soil for surkhi-making in any major work, lime reactivity tests should be carried out on surkhis derived from the soil at different temperatures to find its maximum reactivity and optimum degree of burning. It was also found that iron oxides have an important effect on the pozzolanic activity of surkhis and that red or yellow soils with free iron oxides generally yield better surkhis than black cotton soils. It is recommended that the definition of the terms pozzolan given by F. M. Lea should be ammended to include certain aluminous and ferruginous minerals as well as silicdous materials.

20. Lightweight Concrete Saves on Bridge Steel, Anon. Contractors & Engrs 55: n7, 1958, p 50-2

Lightweight air-entrained concrete made with Haydite expanded shale aggregate reduced the weight added to the deck of the viaduct at St. Louis, Mo., from about 150 to 102 lb/cu ft and allowed a significant reduction in girder size. The 1391-ft viaduct rests on 15 reinforced concrete piers and carries four lanes of traffic and two 26-ft carriage ways with a 4-ft central reserve and 2½-ft footways. The methods of setting the forms, reinforcing and pouring are described.

An electric virbrator and a steel capped vibrating screed were used; the concrete was finished by hand with aluminum floats, dragged with burlap and cured by wet cotton mats. Seven sacks of cement per cubic yard with 200 pounds of Haydite per sack gave a 7-day flexural strength of 500 lb/sq. in.

21. The use of expanded clay aggregate for the preparation of reinforced concrete bridge sections, I. G. Ivanov-Dyatlov, D. N. Ageev and M. A. Litvinenko.
Avtom Dorogi 23: n 2, 1960, p 8-10 (In Russia)

Research by the Moscow Highway Institute (MADI) is described which confirmed that concrete prepared with expanded clay aggregate can be successfully used for the construction of reinforced or prestressed concrete bridge sections. A graphical analysis is presented of results obtained with test beams prepared in the laboratory with 500 kg/cu. m. cement and expanded clay (keramzit) with a density of 500 Kg/cu.m. A saving of 60 roubles per cubic metre of concrete was obtained with almost 30 per cent reduction in weight. Clay concrete beams proved to have greater resistance to crack formation than standard concrete beams but more able to deformation and had a lower modulus of elasticity; flexure was 15 per cent higher but still within acceptable limits.

22. Lightweight Structural Concrete.
Concrete Construction, 6: n 2, Feb 1961, p 32-5

Problems of use of light weight concretes are discussed; facilities for manufacturing expanded slag aggregates, as Kinney-Osborne, Caldwell, and Brosius machines and also jet or pit systems, as nonmechanical means of manufacture, are evaluated; processing of shale, clay, and slate in rotary kiln or sintering on moving grate; tendency of light weight concrete to entrap air pickets and to form honeycomb can be overcome with properly designed mix and by proper vibration; curing requirements.

23. No Fines Concrete, Concrete Construction 6: n 7, July 1961, p 196-8.

Advantages of concretes consisting of coarse aggregate, cement and water-fines being omitted entirely; portion of interconnected voids but with practically no fine capillary pores, about 1/3 less weight, reduced shrinkage, and better thermal insulation; type of aggregate and method of mixing required.

24. Drying shrinkage and creep of expanded shale in lightweight aggregate concrete, B. J. F. Patten.
Constr Rev 33: n 11, Nov 1960, p 29-32.

Comparative investigation of drying shrinkage and creep of lightweight concrete made from expanded shale aggregate from New South Wales and of concrete made from river sand and gravel; lightweight concrete exhibits slightly greater creep strains and its drying shrinkage is considerably less; instantaneous strain is canceled out by end of 3 mo of sustained loading; test procedure and apparatus diagram.

25. Experimental lightweight flat plate structure, Constr Rev 34: n 1, 3, 4, Jan 1961 p 21-32, Mar p 25-33, Apr p 21-6
Jan: Structure consists of lightweight concrete slab 3½ in. thick, 48 by 27 ft in area, and standing on 16 steel box columns 5 feet high; paper deals with measurements taken during construction and on sample specimens up to 28 days after casting; results are given in tables and diagrams. Mar: Analysis of deformations in structure after removal of formwork; comparison between various methods of design analysis of structures.
Apr: Long term deformations in structures.

26. Creep of Lightweight concrete, C. H. Best, M. Polvka. Mag Concrete Research 11: n 33, Nov 1959, p 129-34.

Creep data covering periods of up to 18 mos. for concretes made with expanded-shale aggregates and having compressive strengths of 3000 and 5000 psi at 28 days; comparison with data for sand gravel and concretes of comparable strength; creep in lightweight concrete of equal to or less than that in normal weight concrete of comparable strength; hydraulic loading equipment used in creep tests.

27. Experience is key to profitable haydite production, N. F. Mohler, Brick & Clay Rec 137: n 2, Aug 1960, p 40-2, 67.

Methods used by Carter & Waters Copr of Kansas City for producing lightweight aggregate with rotary kilns; four-kiln plant is at New Market, Mo., and another plant has been completed in Iowa.

28. Experimental flat plate structure of expanded shale concrete. Constr Rev. 33: n 2, Feb 1960, p 22-9

Australian experiments have shown that only important difference between expanded shale concrete and ordinary concrete are in density and modulus of elasticity; any compressive or tensile strengths can be obtained with light concrete as readily as with dense, at same cement factor and appropriate workability; there are some differences in creep; test results given for floor slab supported on steel columns.

29. Lightweight concrete with sintered clay aggregate, R. H. Evans, T. R. Hardwick.
Reinforced Concrete Rev 5: n 6, June 1960, p 369-84 (discussion) 384-400.

Advantages of lightweight aggregates; test results on sintered expanded clay known commercially as Aglite; tests on reinforced beams for ultimate loads, deflections and cracking characteristics, post-tensioned columns for creep and shrinkage losses, columns for modulus of elasticity and pull-out performance, and prestressed concrete beams; measurement of transmission or bond lengths of columns.

30. Use of lightweight cellular screeds, P. Cable.
Insulation (Lond) 4: n 3, May-June 1960, p 127-9.

Consideration of nature of cellular lightweight concrete and distinction between this type of material and lightweight aggregates; factors governing selection and use of cellular concrete insulating material; requirements for insulating material for in situ roof screeds; use of roofing felt and asphalt when laid on lightweight concrete; cause and methods for overcoming blistering by mechanical methods; condensation prevention.

31. Use of lightweight concrete for reinforced concrete construction, A. Short.
Reinforced Concrete Rev 5: n 3, Sept 1959, p 141-88.

Comparison of research data obtained in United States, Germany, Sweden, and in some eastern European countries; corrosive effects of blast furnace slag, colliery shale, boiler clinker, pulverized fuel ash or waste slate on embedded reinforcement; unsolved problems of structural design; adapting lightweight concrete to British standards, 33 refs.

32. Arkalite--New product of Arkansas industry, B. C. Herod.
Pit & Quarry 52: n Oct 1959, p 98-100.

250 cu yd of expanded clay aggregate is produced per day in rotary kiln operation at plant near England, Ark: 8 by 125 ft gas fired roatary kiln, conveyors, and 40 by 33 hammermill described; kiln discharges expanded clay pellets into clinker pit.

33. Control testing for separation of lightweight material from aggregate, E. C. Higginson, G. B. Wallace.
ASTM--Bul n 243, Jan 1960, p 60-8

Method of test, developed in U S Bur Reclamation Laboratories for large scale separation; percentage of lightweight material is determined by sink-float separation in heavy liquid of suitable specific gravity; field experience with method at Glen Canyon Dam; effects of methods of removing lightweight materials, moisture content, rate of absorption of heavy liquid on accuracy, speed and safety of test.

34. Lightweight concrete made with expanded furnace slag, D. W. Lewis, Am Concrete Inst--J 30: n 5, Nov 1958, p 619-33.

Use of ground and screened cinder in cement-sand mortars, in various proportions was tested in India; chemical analysis of cinder and sand used; effects of proportions of mixing on reduction of heat conductivity and on tensile strength; other tests showed that waterproofing by soap treatment is successful also in presence of cinder in mixture.

35. If clay or shale make LW aggregate, J. O. Everhart. Brick & Clay Rec 134: n5, May 1959, p 58-9, 86.

Report on techniques for making accurate preliminary evaluations developed at Engineering Experiment Station, Ohio State University, during study of Ohio materials as sources for lightweight aggregate; stages recommended are analysis by X-ray diffraction methods which may be supported by differential thermal analysis and optical petrography, time temperature density studies and pilot plant studies.

36. Use of fly ash as pozzolan in dense and lightweight concrete, J. T. Tanner, W. M. Kenan. North Carolina State College--Dept Eng Research--Bul n 69, Apr 1958, 26 p.

Pozzolan effect on portland cement is explained and test results given; effects on fresh and hardened concrete, use of pozzolans in foam concrete and in massive concrete; autoclaving of concrete and its economic aspects.

37. Use of fly ash in concrete, C. T. Wanzer. Combustion 30: n 8, Feb 1959, p 38-46.

Present disposal cost of fly ash averages $1 per ton; cost can be greatly reduced if fly ash can be diverted to income producing use; fly ash dispending installations and uses; table of chemical and physical characteristics of fly ash for use in concrete.

38. Goff-Kirby produces foam concrete, R. J. Crouse.
<u>Concrete</u> 66: n 2, Feb 1958, p 30-1, 37.

Foam concrete, which is poured into place, has average compressive strength of 750 psi, and after three days of curing provides excellent base for conventional floor topping; foaming agent in concrete is same as that used in fire equipment.

39. Lightweight-aggregate concrete for structural use, J. J. Shideler.
<u>Am Concrete Inst--J</u> 29: n 4, Oct 1957, p 299-328.

Investigation of properties of lightweight aggregate concrete; program includes tests of plain, conventionally reinforced, and prestressed concrete specimens; data reported on concrete mix proportions, compressive and flexural strength, modulus of elasticity, bond, creep and drying shrinkage.

40. Lightweight structural concrete proportioning and control, G. H. Nelson, O. C. Frei.
Am Concrete Inst--J 29: n 7, Jan 1958, p 605-21.

Physical properties and gradation of expanded shale aggregate produced in Georgia; effect of fine aggregate-coarse aggregate ratio and effect of entrained air on properties of lightweight structural concrete; optimum air content for maximum strength of lightweight concrete recommended.

41. Long-Term expansion of perlite plaster and concrete, R. D. Hill, <u>Australian J Applied Science</u> 9: n 2, June 1958 p141-62.

Study of five perlite aggregates and their raw materials, and of perlite plaster and concretes made with these aggregates; principal cause of long term expansion in perlite plaster and concrete is expansion of aggregate upon rehydration, ion exchange is of minor importance; other factors influencing high rates of expansion and means to prevent this effect.

42. Manufacture and application of lightweight aggregates, T. S. Dickinson, Junior Instn Engrs--J 68: pt 9, June 1958, p263-71.

Review of all porous aggregates used for making them; description of aggregates commonly available and methods of production; special reference is made to Leca, (Light Expanded Clay Aggregate), prominent material in development of prefabricated units of lightweight concrete.

43. Study of Missouri shales for lightweight aggregate, P. G. Herold, P. Kurtz, Jr., T. J. Planje, J. D. Plunkett.
Missouri Geol Survey & Water Resources--Report Investigations n 23, 1958, 39 p.

55 samples of Missouri shales, clays, and loesses were tested for bloating characteristics; 12 samples bloated at commercially feasible temperatures in oxidizing and reducing atmosphere; 10 other bloated satisfactorily in reducing atmosphere only; remaining 33 samples either failed to bloat or bloating tendency was inadequate.

44. Tips on lightweight aggregate handling, K. Nensewitz.
Brick & Clay Rev 132: n 2, Feb 1958, p 54-5, 69.

Information on gradation, segregation, batch variation, moisture compensation, cement-aggregate ratio, and mixing light weight concrete. Exerpt from Materials and Methods Session of Besser School for Block Makers and Block Users.

45. Uniform structural lightweight aggregate concrete through careful proportioning and control, P. J. Fluss.
Am Concrete Inst--J 29: n 12, June 1958, p 1059-62.

Variations in bulk specific gravity of aggregate and construction requirements make necessary careful proportioning, proper control, and adjustment of structural light weight aggregate concrete; experience on Ferry Building, San Francisco, is cited; testing by proportionally changing aggregate weights and added water; tables show proportion of mixes and performances.

46. Hard shell aggregate invades Chicago area, E. Meschter.
Rock Products 61: n 7, July 1958, p 78-81, 128.

Synthetic aggregate, Materialite, made of laminated shale in Ottawa, Ill, plant is 50% lighter; consistent moisture is 6-8%; by burning in kilns, shale pelletizes,expands and acquires tough "skin", 3/4 x 3/8 in. and 3/8 x 0. in. size of raw material are used; concrete products made with Materialite weight 95 lb compared with 150 lb for concrete made with natural aggregate.

47. Idealite--Great Western aggregates producing 750 cu yd daily, H. F. Utley.
Pit & Quarry 50: n 10 Apr 1958, p 138-40-, 146.

Production of Idealite, coated expanded shale lightweight aggregate, at plant south of Laramie, Wyo.; kiln which is 12 ft in diam and 266 ft long discharges to enclosed vibrating grizzly which takes aggregate as it comes from cooler cylinders; details of screening and storage equipment; physical properties of Idealite given.

48. Mechanism of lightweight aggregate formation, E. G. Ehlers, Am Cer Soc--Bul 37: n 2, Feb 1958, p 95-9.

Study of mechanism involved in bloating of six shales and clays for use in brick and concrete, from chemical and mineralogical viewpoints; bloating was effected and gases causing bloating were collected and analyzed by chromatographic method; relationships between firing temperature, particle size of materials time in kiln, and effects of preheat are discussed.

49. How Trulite is made from coal refuse, K. A. Gutschick. Rock Products 59: n 11, Nov 1956, p 70-3, 120.

New manufactured lightweight aggregate is lighter than coal cinders; manufacturing process involves burning coal which resulting cinder cake is cooled, crushed, and sized prior to shipment.

50. Lightweight aggregate, B. C. Herod Pit & Quarry 49: n 9, Mar 1957, p 162-3, 166-7.

Production and use of Barlite, lightweight aggregate at Barrett Industries, San Antonio, Texas; raw material is clay which analyzes 65% silicon, 20% aluminum, and 5% iron compounds; products include lightweight concrete masonry units, concrete sewer pipe and drain tile, and ready mixed concrete.

51. Use of foam in concrete, J. L. Hanold. Concrete 64: n 4, Apr 1956, p 32-4.

Review of various methods of producing very low density concrete; air entrainment; cellular concrete and how various textures are obtained; foaming processes including mechanical mixing and method in which solution of foam liquid is mixed with compressed air.

52. Future of structural concrete, R. F. Blanks, Western Construction 31: n 5, May 1956, P 38-40.

Precasting, prestressing, and lightweight aggregates which have made possible new uses for structural concrete; discussion of past and future of concrete, with emphasis on production and effects of lightweight aggregates as new structural materials are produced; comparison of standard and lightweight concrete; characteristics of coated expanded shale.

53. Lightweight aggregates for structural concrete, A. Pauw. Am Soc Civ Engrs--Proc 81: Separate n 584, Jan 1955, 14 p

Lightweight concretes may be produced by formation of air voids in cement paste, formation of air voids in concrete by omitting fine aggregaes, and use of lightweight aggregates which owe their low density to presence of enclosed structural concrete and their effect on design; economic considerations.

54. Some preliminary studies on compositions of lightweight structural shapes by foam methods, R. G. Hardy.
<u>Kansas State Geol Survey--Bul</u> n 109, 1954, p 1-12

Use of pozzolanic materials for manufacture of lightweight aggregates; three methods of introducing foams; whipping foam in suitable slurry, generating gases in mix, and mixing slurry and preformed foam, subsequent autoclaving is usually employed where structural strengths are desired in products.

55. Variation in density of lightweight concrete aggregates, H. S. Sweet, <u>Am Soc Testing Matls--Bul</u> n 184, Sept 1952, p 44-7.

Tests of specific gravity, absorption, and concrete properties of different gradations of lightweight aggregates; influence of variation in specific gravity for different particle size on problem of specifying sieve analysis limits on weight, basis and on design of concrete mixes for workability; it is concluded that certain modifications should be made in grading specification for aggregates.

56. Lightweight aggregate concrete, R. W. Kluge, M. M. Sparks and E. C. Tuma.
<u>Am Concrete Inst--J</u> 20: n 9, May 1949, p 625-42, (discussion) v 21: n 4, pt 2, Dec p 644 (4p); see also Ice & Refrig 117: n 3, Sept 1949, p 24-6

Studies made by Nat'l Bureau of Standards; aggregates studied were expanded clay, shale and slate, expanded blast furnace slag, expanded vermiculite and perlite, sintered diatomite, fly ash and pumice; test results summarized.

57. Lightweight pumice concrete, A. E. Niederhoff.
<u>Am Soc Civ Engrs--Proc</u> 75: n 6, June 1949, p 743-57, (discussion) n 9, Nov p 1387.

Because of its light weight and insulating qualities it has been found feasible and economical to ship pumice as far as 300 miles for use in building construction; material weighs about one half as much as conventional concrete, has strength up to 3500 psi, low heat conductivity and is nailable.

58. Production of lightweight concrete aggregates from clays, shales, slates, and other materials, J. E. Conley, H. Wilson, T. A. Klinefelter and others.

U. S. Bur Mines--Report Investigations n 4401, Nov. 1948, 121 p supp plates.

Industrial Research and Development Division of Office of Technical Services, U. S. Department of Commerce, has entered into contract with Bureau of Mines to assist in research aimed at stimulation of industrial production of larger quantities of light weight concrete aggregates; results of investigation under contract to date.

59. Results of research on lightweight concretes, E. G. Molander.
Agri Eng 30: n 3, Mar 1949, p 129-30, 133.

Discussion of porous concretes, foam and gas concretes, and organic filler concretes; their use for agricultural purpose.

60. Story of pumice.
Concrete 56: n 10, 12, Oct 1948, p 8-10, 34, Dec p 3-5, 37.

Oct: Application of pumice concrete to Jackson County Memorial Hospital at Altus, Okla.; deadweight reduced to 50% thus making possible saving of 45% of reinforcing steel; high thermal insulation value eliminated need for roof insulation; cost of typical bay of school building was $963.29 with normal concrete against $822.64 with pumice concrete; proportioning.
Dec: Manufacture and tests of concrete masonry units; facilities and products of Harter Marblecrete Stone Co., Oklahoma City, Oklahoma.

61. Design and control of pumice concrete mixes, W. K. Wagner.
Rock Products 51: n 9, Sept 1948, p 125-7, 136-8.

Chemical analysis of pumice; tests made to determine strength relationships in mixes of workable and plastic consistencies water cement ratio and relation of modulus of elasticity to compressive strength for pumice mixes plotted in alignment charts; study of effect of air entraining.

62. Properties of some lightweight-aggregate concretes with and without air-entraining admixture, P. H. Petersen.
U S Bur Standards--Bldg Matls & Structures--Report BMX112, Aug 16, 1948, 7 p.; see also Am Concrete Inst--J 20: n 2, Oct 1948, p 165-75.

Aggregates made with burned shale or explaned slag; three grades of concrete using each aggregate were made; air entrainment of greater than 20% is reported for mixtures leanest in cement; compressive, transverse, and bond strength; coefficients of thermal expansion, shrinkage, and values for change in length due to wetting and drying.

63. Studies of lightweight concrete mix design and strength, E. L. Howard. Rock Products 51: n 6, June 1948, p 189.

Report on studies of concrete made from natural aggregates; comparative unit weights, compressive strengths and physical and chemical analysis of scoria and pumice from Siskiyou County tabulated; comparative mix and compression data of concrete using scoria (pebbled) aggregate.

64. Recent developments in lightweight concrete, T.W. Parker. Roy Inst Brit Architects--J 52: n 2, 4, Dec 1944, p 43-7, (discussion) Feb 1945, p 100-2

Properties of concrete made with lightweight aggregates such as clinker, pumice, shales, clays and expanded vermiculite; strength, water absorption and heat insulation discussed. Bibliography.

65. Effect of curing condition on compressive, tensile and flexural strength of concrete containing haydite aggregate, E.B. Hanson Jr., and W. T. Neelands. Am Concrete Inst--J 16: n 2, Nov 1944, p 105-14.

Results of tests on lightweight concrete used in barges to determine cause of extensive cracking of concrete experienced in similiar structures.

66. Properties of porous concrete of cement and uniform sized gravel, P. H. Petersen. U S Bur Standards--Bldg Matls & Structures--Report BMS 96, Mar 18, 1943, 15 p.

Physical properties of porous concrete consisting solely of portland cement, water, and uniform sized gravel were investigated; compressive, transverse, shearing, and bond strengths are reported as well as resistance to heat transfer; water penetration by capillarity, and rain penetration.

67. Lightweight aggregates for concrete, F. T. Moyer. U S Bur Mines--Information Cir n 7195, Jan 1942, 26 p; see also Cer Age 40: n 5, Nov 1942, p 152-4.

Comment on need for and advantages of light weight building materials; kinds of aggregates; properties and uses; natural aggregates; by-product aggregates; processed aggregates; market summary.

68. Design of light-weight zonolite concrete mixes, G.P. Tschebotareff. Am Concrete Inst--J n 4, Feb 1941, p 509-15.

Results of tests, illustrating peculiarities of such mixes which necessitate special approach to problem of their design; determination of advisable water content.

69. Properties of lightweight aggregates and lightweight concretes, G. W. Washa, Am Concrete Inst--J 28: n4, Oct 1956, p 375-82.

History of use of lightweight aggregates; lightweight concrete is divided into; cellular or foam, no-fines or "popcorn", and lightweight aggregates concrete; lightweight aggregates, both mineral and vegetable, are enumerated; desirable properties of mineral aggregates discussed.

70. Structural lightweight-aggregate concrete, R. W. Kluge. Am Concrete Instn--J 28: n 4, Oct 1956, p 383-402.

Proportioning and control of concrete mixtures containing lightweight aggregate, some of physical characteristics of plain concrete, as well as certain structural properties of reinforced lightweight concrete with comments on their relation to design of structural elements.

71. Arizona volcanic cinder concrete, a comparative study, A. W. Ross, K. K. Kienow., Engineering Experiment Station Bulletin No. 9, The University of Arizona, Civil Engineering Series No. 4, May 1959, e 32+.

Since very few studies have been made with comparable types of material, this program has entailed investigations relative to the basic aggregate properties, the relation of the aggregates to concretes of several different designs, appropriate testing methods, and the establishment of design criteria for general field use.

To date these investigations have included work with two different types of cinders in combination with two types of fine aggregate toward establishing design criteria. Additionally, investigations of the modulus of elasticity and bond strengths for several designs are now being conducted.

72. The tensile strength and diagonal tension resistance of structural lightweight concrete, J. A. Hanson. Research and Development Laboratories, Portland Cement Association, January, 1961, 61 p.

This report describes the tests employed and the results obtained in an extension of a previous study of diagonal tension resistance reported by the author; this extension of the original program involves lightweight concrete beams of longer span and lower steel percentages. An important conclusion, that diagonal cracking load should be considered as the ultimate load for non-web reinforced beams, has been confirmed.

A large number of 6 x 12 in. cylinders from the beam concretes were broken by the "split-cylinder" tension test. Good correlation was established between this indirect tension measurement and the shear resistance of the beams at diagonal cracking. This correlation shows that the diagonal tension resistance of lightweight concretes varies from approximately 60 percent of that of the similar normal weight concrete to nearly 100 percent, depends upon the particular lightweight aggregates used.

Proposed ultimate load design recommendations are made for structural lightweight concrete. These are in general accord with the recommendations of the ACI-ASCE Committee 326 on Shear and Diagonal Tension for normal weight concrete. It has been found that diagonal tension strength of the lightweight concretes is affected by the same variables as effect the resistance of normal weight concrete. The difference between the two types of materials is one of magnitude of diagonal tension and resistance and not of fundamental difference in behavior.

The proposed design recommendations also provide for the fundamental differences in tensile resistance that exist between the various lightweight aggregates. A combination of compressive strength and split-cylinder tension testing provides a convenient and safe measure of the ultimate diagonal tension resistance to be associated with each of the various aggregates.

73. A Study of Lightweight Aggregate for Structural Use, M. Barrett Clisby and J. G. Wallace, Mississippi State University, Engineering and Industrial Research Station (State College, Miss.). Sept. 1964, pp. 127.

The primary objective of this study was to develop design and economic criteria for the utilization of lightweight concrete in prestressed concrete bridge girders. The secondary objective was to devise a method of determining the modulus of concrete in bending and to compare the results with the modulus obtained from standard axial tests of plain concrete cylinders. This investigation was undertaken to determine the physical characteristics of a particular lightweight aggregate concrete. The lightweight aggregate considered is an expanded clay which is produced by a rotary kiln process in Jackson, Miss. Comparative tests were conducted on hard-rock concrete.

Six 40-ft prestressed beams and over 100 cylinders and prisms were tested to destruction. The lightweight aggregate concrete compared favorably with the hard-rock concrete. It was, however, more easily damaged in handling.

74. Critical Mechanical Properties of Structural Lightweight Concrete and the Effects of These Properties on the Design of the Pavement Structure.

William B. Ledbetter, Ervin S. Perry, James T. Houston, and J. Neils Thompson. Res. Rept. No. 55-3F, Center for Highway Research, Univ. of Texas, Austin, Texas, Jan. 1965 82pp.

Critical mechanical properties resulting from unrestrained and restrained volume changes. Particular attention is given to compressive direct tensile, and indirect tensile (split cylinder) strength is at various ages of the concrete.

The critical properties determined indicate that concrete pavements can be designed with lightweight concrete and that expected performance in regard to the effects of warping stressed and pavement deflection will be better when lightweight concretes are used. However, the effects of restrained volume change of lightweight concrete on pavement performance can be detrimental if improper curing, or curing for too short a time occurs. The need for further research into the effects of curing on lightweight concrete pavement performance is emphasized.

75. Investigation of Properties of Lightweight Concrete, Dean C. McKee and H. T. Turner, Louisiana State Univ. (Baton Rouge,La.) Division of Eng. Res., Eng. Res. Bull. No. 74, 1964, 70 pp.

Results are reported of a study of the shrinkage characteristics of structural quality lightweight concrete. Aggregate absorption and volume change characteristics are the principal reasons for the differences in behavior between these lightweight concrete mixes and comparable sand and gravel mixes. The aggregates absorb moisture from the mix to such an extent that slump and water/cement ratio have meaning unless qualifying conditions are stated. The aggregates change volume with changes in absorbed moisture so that measurable specimen shrinkage is increased up to twice that of comparable sand and gravel specimens. Curing conditions are most important in-so-far as shrinkage is concerned.

The techniques used for the determination of shrinkage during the first 24 hours after a specimen has been cast and of aggregate volume changes with absorbed moisture appear promising however, additional studies in these areas are justified.

When initial aggregate moisture is the only variable, the unit weighs of the various specimens tend to approach the same value if the same storage conditions are maintained.

Lightweight aggregate concrete specimens may be prepared with compressive strengths comparable to companion sand and gravel specimens with high air contents. The tensile strengths (at 28 days) will not usually compare favorable to those obtained from sand and gravel concrete, probably due to almost 100 percent aggregate fracture on the failure plane for lightweight aggregate and less than 20 percent for gravel.