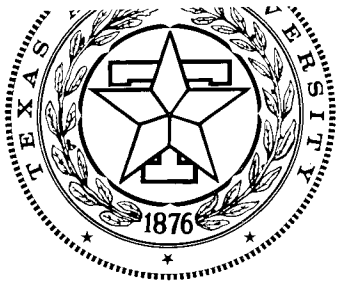

TEXAS TRANSPORTATION INSTITUTE

TEXAS HIGHWAY DEPARTMENT

COOPERATIVE RESEARCH

DIAGONAL TENSION RESISTANCE OF LIGHTWEIGHT CONCRETE
2-8-54-1

in cooperation with the
Department of Commerce
Bureau of Public Roads

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DIAGNAL TENSION RESISTANCE OF LIGHTWEIGHT CONCRETE

Compiled by
Texas Transportation Institute
February 1964

1. Hanson, A.J., "The tensile strength and diagonal tension resistance of structural lightweight concrete." Portland Cement Association Bulletin D50,Reprint from the Journal of the American Concrete Institute July 1961. Proceedings 58: p 1

   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 6x 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 sheer resistance of the beams at diagonal cracking. This correlation shows that the diagonal tension resistance of lightweight concretes varies from approximately 60 per cent of that of the similar normal weight concrete to nearly 100 per cent, depending on the particular lightweight aggregates used.

   Proposed ultimate load design recommendations are made for structural lightweight concrete. These are in ganeral 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 affect the resistance of normal weight concrete. The difference between the two types of materials is one of magnitude of diagonal tension resistance and not of fundamental difference in behavior.

   The proposed design recommendations also providefor 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.

2. Mitchell, Neal B., Jr., "The indirect tension test for concrete." Materials Research and Standards (ASTM) 1: n 10, pp 780-88 October 1961.

   The purpose of this paper is to evaluate the indirect tension test as a standard measure of tensile strength for concrete and other brittle materials. Present and proposed tension testing procedures are compared theoretically and experimentally with the indirect tension test.

Evaluation of the various failure theories indicates that the Mohr failure theory is a satisfatory representation of the failure conditions in this test. Mathematical considerations assume elasticity to failure., and the stress conditions are evaluated for both points and distributed loads.

Test data on high-strength concrete cylinders are compared with other published results from their test and also with results of tensile strength measurements using other tests. Moisture, testing speed, plate size, plate type, and cylinder size are considered with respect to their effect on test results. Basic recommendations are advanced for this test procedure.

Indirect tension test results using Keene's cement cylinders are presented, and unique fracture characteristics are explained.

3. Moe,Johannes, "Diagonal tension in reinforced concrete beams." Nordisk Betong 6: n 1, pp 89-104, 1962. (In Swedish)

This paper presents a review of recent findings in the study of sheer strength of reinforced concrete beams. It is shown that the classical formula (1) does not give a true picture of the danger of shear failure. New design procedures suggested or in use in the USA and the USSR are discussed.

A hypothesis for the mechanism of inclined crackingin beams with long shear spans is discussed. In this hypothesis it is suggested that the portion of a beam between two neighboring bending cracks should be treated as a cantilever loaded by forces due to the flexual reinforcement and by shear forces transmitted across the bending cracks.

It is furthermore suggested that the magnitudes of the shear forces transmitted across the bensing cracks gradually decrease when the crack widths increase. This causes higher stresses in the cantilever. Since the cracks widths in a beam with long shear spans will be relatively large, such a beam may be expected to fail in inclined tension owing to the destruction of the cantilever at a relatively low load.

Tests are suggested in which the formation of inclined cracks is recorded by high speed cameras. Close attention should also be paid to the widths of the bending cracks and to the tensile stresses in the cantilevers between the cracks.

4. "Shear and diagonal tension." Am Concrete Institute Jno.3, March 1962, p 353-395. Report of ACI-ASCE Committee 326.

Pt. 2 Beams and frames. A review of scientific knowledge, engineering practice, and construction experiences regarding shear and diagonal tension in reinforced concrete beams, frames, slabs, and footings.

5. Thaulow, S., "Tensile splitting test and high strength concrete test cylinders." J Amer Concr Inst 28: (Proc 53), n 7 1957, p 699-706.

This paper deacribes an indirect tensile test for determining the tensile splitting strength of concrete and a Norwegian method of preparing cylindrical specimens in which sufficient compaction of the concrete is obtained, and capping for compression testing is eliminated. This method of making cylinders is said to be of particular value for high strength concrete, where thickness and quality of the capping material may have considerably more effect on the compressive strength test results than for lower strength concretes.

6. "Trend in Engineering." (University of Washington) 14: n 3, July 1962, p 18-23, 32.

Materials, fabrication, and test procedure.

7. Upton, George M. Jr. and Jack R. Clanton, " An investigation of diagonal tension resistance in beams made with a lightweight aggregates." Trend in Engineering, Univ of Washington 14: n 3, pp 18-23, 32, July 1962.

This paper describes the investigation of diagonal tension resistance in beams made from a lightweight expanded shale concrete. Thirty-six beams with a span length of 4 ft and a gross cross section of 4 by 8 in. were cast.

This series of studies involved the effects of four variables upon the diagonal tension resistance in these beams. The variables employed were shear span, amount of tensile reinforcement, concrete strength, and percentage of web reinforcement.

The following conclusions have been drawn from the results of this investigation: (1) the nominal shearing stress at ultimate load, v_u, increases with an increase in cement content; (2) the nominal ahearing stress at ultimate load, v_u, increases with an increase in the amount of longitudinal steel; (3) both v_c, the nominal shearing stress at siagonal cracking, and v_u, the nominal shearing stress at ultimate load, v_u, increases as the stirrup spacing decreases in beams that fail in diagonal tension, but the relationship is non-linear: (5) the tensile strength obtained from the split-cylinder tests appears to be a reliable measure of unit-shear strength at diagonal cracking; (6) Hanson's proposed design equation for beams withour web reinforcement is reliable in all cases, but is too conservative

for beams with an a/d ratio of less than 2.5; (7) the present ACI code provision for members not web reinforced is unsatisfactory; (8) the ACI-ASCE Committee 326 proposed ultimate design equation for web-reinforced members was applicable to the test beams that failed in diagonal tension.

8. Van Riel, A.C. and L. Wijler, " A new indirect tensile test for concrete. Theoretical analysis and preliminary experiments." Bull. Res. Coun. Israel. C. Technol. 6C: n 1, p 13-27, 1957.

The tensile strength of concrete cubes may be determined from dimensions of the failure section when a compressive load is applied along the middle of two opposite faces. The problem has been investigated (a) theoretically, by solving the plane-strain problem of a square acted upon by two equal and opposite forces; (b) byphotoelastic testing of two identically loaded slabs, one square and one circular, and comparing the isochromatic and isoclinic lines obtained; and (c) by testing concrete cubes and cylinders in indirect tension and unreinforced beams in bending, and comparing the results. It is stated that all cubes tested failed along a diametrical plane containing the load, thus confirming the theoretical calculations assigning the maximum tensile stress to this plane; the tensile strength determined theoretically was in close agreement with that obtained by the other two methods; and the tensile strength of prisms was about 80 percent higher than that of cubes and cylinders, which appears to be caused largely by non-linear stress distribution.

9. Wright, P.J.F., " Comments on an indirect tensile test on concrete cylinders." Mag of Concrete Res (England) 7: n 20, p 87-96, July 1955.

A test which originated in Brazil for determining the tensile strength of concfete involves applying a compressive load to opposite generators of a cylindrical specimen. The specimen failsin tension along the diametrical planecontaining the load.

Experiments with this test have shown that: (1) Packing strips of relatively soft material are necessary between the specimen and the platens of the testing machines. Plywood strips ½ inch wide and 1/8 inch thick are satisfactory for the purpose, but the material and dimensions of the strips have little effect, provided they can conform to small irregularities in the surface of the specimen. (2) Cylinder 6 inches in diameter by 6 inches long may be used for concrete containing aggregate up to 3/4 inch maximum size. Longer specimens may tend to give higher average values. (3) The new test gives results higher than those given by a direct tensile test but lower than the modulus of rupture of beams. It tends to give more uniform results than the direct tension or transverse test, but less uniform results than a compression test on cubes.