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Contents of this issue on page 5

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REINFORCED CONCRETE DESIGN

DESIGNING REINFORCED CONCRETE COLUMNS, FLOOR SLABS, BEAMS, GIRDERS AND ARCH SECTIONS WITH THE AID OF NEW GRAPHIC DIAGRAMS.

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WHILE diagrams do not usually afford the same accuracy obtainable from analytic computations, yet no extreme accuracy is ever required in concrete design since the nature of the material and its changes with age render concrete far more uncertain than steel. The best standard steel specifications permit a 10% variation in ultimate strength and about 2% variation in the cross-sections of finished members, to say nothing of the inaccuracies in the assumed dead and live loads. With concrete, these variations are admittedly greater, and hence no extreme accuracy can be exacted in reinforced concrete designs.

Therefore, if graphic diagrams can be made to yield results within 5% of computed values, no valid objection can be raised against their use. Generally the results will be much better and gross mistakes are practically eliminated, because each result can be so easily checked by a repetition of the readings taken.

The formulae here used are based on the usual assumption that the concrete takes no tension, and that the compressive stress in the concrete varies directly as the distance from the neutral axis.

Where double reinforcement is employed, it will always be taken symmetric, and the compression will be carried by both steel and concrete, while tension, if present, will be carried by the steel alone.

These assumptions accord well with the facts, and lead to the formulae given below, which are now almost universally accepted.

The allowable working stresses for concrete, as given in Table II., are based on Class A concrete, consisting of granite, trap rock, gravel or hard limestone in sizes not exceeding ¾-inch for small form work to 1½-inch for heavy beams and columns. This stone aggregate is mixed with clean, sharp sand and Portland cement in the stated proportions.

As a specification for quality of Class A concrete, 12-inch cubes, when tested to crushing, must develop an ultimate compressive strength not less than the values given in Table I. for one month and six months after mixing.

The unit working stresses adopted are based on a factor of safety of five, or slightly over, for concrete at the age of 6 months, which is considered good conservative practice. The modular ratio n is taken as 15 for average working conditions.

TABLE I.

ULTIMATE COMPRESSIVE STRENGTH (Pounds per Square Inch), Class A Concrete.

Concrete mixture, parts by volume.	1 month.	6 months.
1 : 1.5 : 3	2,600	3,400
1 : 2 : 4	2,200	3,200
1 : 2.5 : 5	2,000	3,000
1 : 3 : 6	1,800	2,800

The column formulae used are those given in Turneaure and Maurer's "Principles of Reinforced Concrete Construction, 1909," page 271. Diagram 1 gives the allowable unit working stress for columns with longitudinal reinforcement only, and for columns with hooped or spiral circumferential reinforcement, with proper reduction for columns longer than 10 d. The safe working stress for the concrete alone is given in Table II. under heading columns. See examples for illustration.

The beam and slab formulae employed are given on the annexed sheets and are also to be found in the above-named treatise. These are based on the fundamental equation $k = \sqrt{2pn + (pn)^2} - pn$, first proposed by Coignet and Tedesco, for locating the position of the neutral axis in terms of the modular ratio n and the steel ratio p, where k is the fractional part of the net depth d which the neutral axis is below the extreme fibre on the compression side. Diagrams 2, 3, 4 and 5 furnish beam and steel dimensions for all externally applied bending moments up to one million foot-lbs. for slabs or beams one foot wide. These dimensions are based on such values of p for which the moment of resistance of the concrete equals the moment of resistance of the steel and hence lead to economic designs. These diagrams are, of course, applicable to beams of any width merely by correcting the applied bending moment to the equivalent for 1 foot width.

Direct stress and bending. Diagrams 6, 7 and 8.—The formulae for solving this problem are quite complex, hence the solution by curves should prove most welcome