

IN-LB

Inch-Pound Units

SI

International System of Units

Assessing Combined Aggregate Gradings— Guide

Reported by ACI Committee 211

ACI PRC-211.10-24



American Concrete Institute
Always advancing



Assessing Combined Aggregate Gradings—Guide

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. Despite these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at <http://concrete.org/Publications/DocumentErrata.aspx>. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided “as is” without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations regarding health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

ACI documents are written via a consensus-based process. The characteristics of ACI technical committee operations include:

- (a) Open committee membership
- (b) Balance/lack of dominance
- (c) Coordination and harmonization of information
- (d) Transparency of committee activities to public
- (e) Consideration of views and objections
- (f) Resolution through consensus process

The technical committee documents of the American Concrete Institute represent the consensus of the committee and ACI. Technical committee members are individuals who volunteer their services to ACI and specific technical committees.

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

Assessing Combined Aggregate Gradings—Guide

Reported by ACI Committee 211

Ezgi Wilson,* Chair

Michael A. Whisonant, Secretary

Kamran Amini
William L. Barringer
Katie J. Bartojay
Muhammed P. A. Basheer
James C. Blakenship
Casimir J. Bognacki
Peter Bohme
Anthony J. Candiloro
Ramon L. Carrasquillo
Bryan R. Castles
Teck L. Chua

John F. Cook
Kirk K. Deadrick
Bernard J. Eckholdt
Joshua J. Edwards
Timothy S. Folks*
David W. Fowler
Brett A. Harris
G. Terry Harris
T. J. Harris
Lance S. Heiliger
Richard D. Hill

David L. Hollingsworth
Tarif M. Jaber
Robert S. Jenkins
Joe Kelley
Gary F. Knight
Eric P. Koehler*
Frank A. Kozeliski
Robert C. Lewis
Tyler Ley[‡]
John J. Luciano
Darmawan Ludirdja

Allyn C. Luke
Kevin A. MacDonald
Ed T. McGuire
Karthik H. Obla
H. Celik Ozyildirim
James S. Pierce
Steven A. Ragan
G. Michael Robinson
James M. Shilstone*
Lawrence L. Sutter

*Also member of ACI 211-I Subcommittee.

[‡]Chair of Subcommittee ACI 211-I.

Additional ACI 211-I Subcommittee Members

Patrick J. Harrison, Co-Chair

Mohamadreza Moini

Hadi Rashidi

Consulting Members

Donald E. Dixon
Said Iravani

James N. Lingscheit
Royce J. Rhoads

Ava Shypula

Note: Special acknowledgment to D. Cook for his contributions to this guide.

This guide provides background and examples on the use of practical aggregate grading tools to improve aggregate performance in concrete and allow the paste content of a concrete mixture to be reduced while achieving satisfactory workability and physical properties. The aggregate grading of a concrete mixture impacts the workability, durability, strength, and sustainability of concrete. These grading tools can also be used to proportion concrete mixtures as well as troubleshoot issues associated with mixtures from high to low workability. This guide does not make recommendations, but it does describe and give examples on how to use these tools.

Keywords: aggregate; aggregate grading; coarseness factor chart; gap graded; individual percent retained (IPR) chart; particle shape; Power 45 curve; proportioning aggregate; tarantula curve; well-graded aggregate.

ACI Committee Reports and Guides are intended for guidance in planning, designing, executing, and inspecting construction. This document is intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the information it contains. ACI disclaims any and all responsibility for the loss or damage arising therefrom. Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

CONTENTS

CHAPTER 1—INTRODUCTION AND SCOPE, p. 2

1.1—Introduction, p. 2

1.2—Scope, p. 2

CHAPTER 2—NOTATION AND DEFINITIONS, p. 2

2.1—Notation, p. 2

2.2—Definitions, p. 2

CHAPTER 3—THEORY OF GRADING TECHNIQUES, p. 2

3.1—Introduction, p. 2

3.2—Combined aggregate grading techniques, p. 2

3.3—Individual percent retained chart, p. 3

3.4—Tarantula curve, p. 3

3.5—Coarseness factor chart, p. 5

3.6—Power 45 chart, p. 5

ACI PRC-211.10-24 was adopted and published in December 2024.

Copyright © 2024, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietors.

3.7—Incorporating the aggregate grading into the mixture design, p. 6

CHAPTER 4—APPLYING GRADING TECHNIQUES, p. 6

- 4.1—Introduction, p. 6
- 4.2—Example I: three-aggregate system for slip-formed pavement, p. 6
- 4.3—Example II: four-aggregate system for footings, walls, and floor slabs, p. 9
- 4.4—Example III: four-aggregate system for an airport runway using a slip form paver, p. 11
- 4.5—Example IV: two-aggregate system for slip formed pavement, p. 13
- 4.6—Example V: two-aggregate system for footings, walls, and floor slabs, p. 15
- 4.7—Example VI—three-aggregate system for slip formed pavement, p. 19

CHAPTER 5—SUMMARY, p. 24

CHAPTER 6—REFERENCES, p. 24

Authored documents, p. 24

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Aggregates make up approximately 75% of the volume of a concrete mixture and, therefore, aggregate can affect the strength, workability, pumpability, finishability, shrinkage, and durability of concrete (Cook 2015; Richard 2005; National Stone, Sand, and Gravel Association 2013; Kosmatka and Wilson 2016; Taylor et al. 2007). Many different mixture design methods exist for concrete, and they have different methods to address aggregate (Cook 2015; Richard 2005; National Stone, Sand, and Gravel Association 2013; Kosmatka and Wilson 2016; Taylor et al. 2007; Abrams 1918; Powers 1968; Goldbeck and Grey 1968; Shilstone 1990). All of these design methods identify the importance of the size distribution or grading of the aggregates to proportion coarse and fine aggregates. The methods in this document use a combined aggregate grading to improve packing and minimize paste content. It should be noted that even if an aggregate grading meets the suggested combined grading limits, this is not a guarantee that the mixture will produce a satisfactory concrete mixture and, therefore, adjustments to mixture proportions may be needed with trial batches. Practitioners have found mixtures with combined aggregate grading techniques to be more consistent, show increases in strength and a reduction in water demand, and allow a lower paste content when combined grading techniques are used (Cook 2015; Powers 1968; Goldbeck and Grey 1968; Shilstone 1990; Shilstone and Shilstone 1989).

1.2—Scope

This document provides some background literature and examples to help develop a combined aggregate grading

for concrete mixtures from high to low workability using different aggregate grading techniques.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

- C = cementitious material content, lb/yd³ (kg/m³)
- D = maximum coarse aggregate size
- d = current sieve size
- P = value on x-axis for a given sieve size
- Q = cumulative % retained on the 3/8 in. (9.5 mm) sieve
- R = cumulative % retained on the No. 8 (2.36 mm) sieve
- W = cumulative % passing the No. 8 (2.36 mm) sieve size

2.2—Definitions

Please refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions. Definitions provided herein complement that resource.

coarse sand—summation of the material retained on the No. 8, No. 16, and No. 30 (2.36 mm, 1.18 mm, and 600 μm) sieve size of the tarantula curve.

coarseness factor chart—graphical aggregate grading technique that uses the coarseness factor and workability factor to examine the aggregate grading.

fine sand—summation of the material retained on the No. 30, No. 50, No. 100, and No. 200 (600 μm, 300 μm, 150 μm, and 75 μm) sieve size of the tarantula curve.

individual percent retained chart—graphical aggregate grading technique that plots the percent mass retained on each sieve and compares this to an established limit.

Power 45 chart—graphical aggregate grading technique that compares the cumulative mass passing for each sieve raised to the 0.45 power.

tarantula curve—graphical aggregate grading technique that plots the percent mass retained on each sieve and compares this to an established limit with the shape of a tarantula. Additionally, two fine aggregate equations are used to calculate the fine sand and coarse sand and compare them to established limits.

CHAPTER 3—THEORY OF GRADING TECHNIQUES

3.1—Introduction

Aggregate grading techniques aim to increase the volume of aggregates through improved packing while decreasing the volume of paste to enhance the workability and other properties of the concrete. While no single aggregate grading procedure considers all mixture requirements, such as the aggregate size distribution, cementitious materials, admixture combinations, maximum aggregate size, passing ability, segregation resistance, or pumpability, practitioners continue to use aggregate grading techniques because of observed improvements in performance (Obla and Kim 2008; McCall et al. 2005; Varner 2010).