Gravel Pack Design: The Nexus of Theory, Experience and Personal Preference

Introduction

It is widely accepted that a properly designed and installed, graded gravel pack will enhance a well's efficiency and will control the migration of fine formation sand into the well. These and other value-added aspects of a gravel pack are collectively the reasons that the majority of municipal, industrial, and agricultural water wells are completed with gravel envelopes. However, while there is general agreement on the utility of a graded gravel pack, there seems to be no consensus on the best approach to designing the gravel pack. As with most things engineered, there is no shortage of opinions on gravel pack design.

Over the past 80+ years since Karl Terzaghi authored *Theoretical Soil Mechanics* in 1943, numerous technical papers and articles have described various approaches to engineer a gravel pack. Typically, they espouse the importance of various gravel pack design considerations such as pack thickness, grain size sorting (or grading), the ideal uniformity coefficient and effective size, and parameters for the pack-aquifer ratio. Each author offers various charts, ratios, and design criteria, all intended to guide the designer toward the selection of an appropriately graded gravel pack for a given formation.

Faced with the myriad opinions on gravel pack design, the designer is faced with an important decision: Which method(s) should I choose? Based on our own personal experiences, we believe that many designers make this choice based on factors such as:

- Understanding of the various design methods
- Guidance from colleagues or directions from supervisors
- Personal preference

In surveying the various gravel pack selection methods, it is apparent that every design method is guided by two tenets. Ultimately, the gravel pack should:

- Enhance the efficiency of the well, and
- Control the migration of sand from the formation to meet the performance requirements of the project.

Key Definitions

Several important terms in common usage are defined below:

1. d_x - Sizes of the individual particles wherein *x* percent is smaller. In other words, d_x is the percent passing.
2. *Uniformity coefficient* – the ratio of the d_{60} to the d_{10} sizes.
3. *Pack-Aquifer ratio* – the ratio of the d_{50} size of the gravel pack to the d_{50} size of the aquifer.
4. *Formation Stabilizer* – a gravel envelope whose primary purpose is to fill the annular space between the borehole and the well casing and screen in unstable formations, preventing sloughing.

Example Design Methods

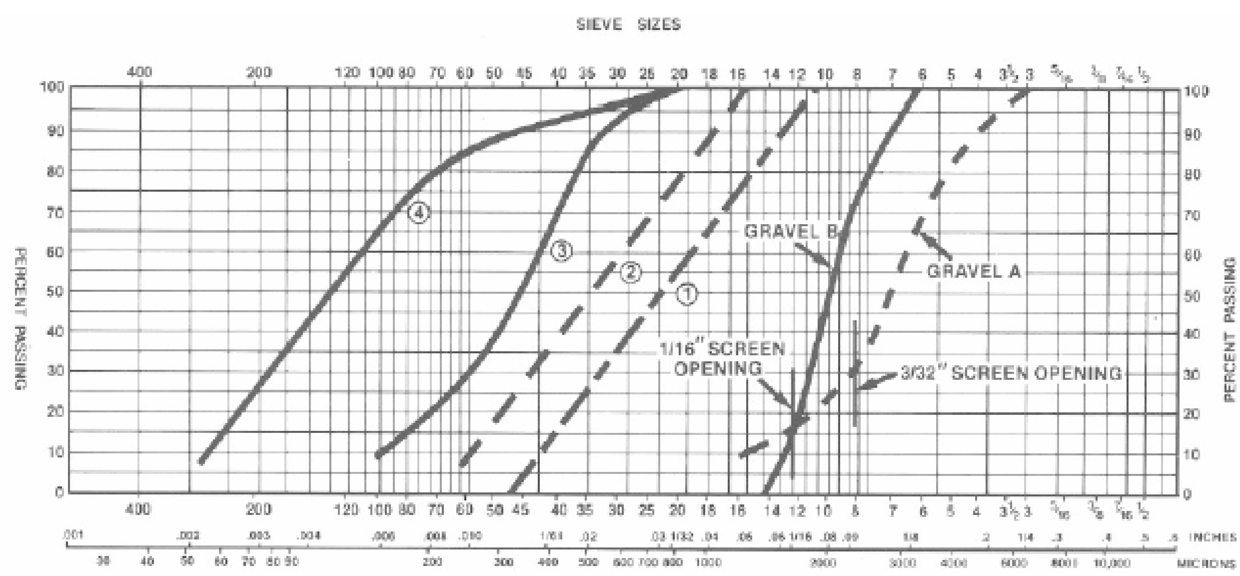
As an introduction to gravel pack design, we selected two example methods and prepared the following brief overviews. We want to emphasize that this memorandum is not suggesting that one method is better than another. Our own experience has shown that despite the differences between these two methods, each has produced satisfactory results. Other gravel pack design methods are presented in the reference list.

<u>Method No. 1</u>: Working with the d_{30} Size

a. Plot the sieve results for all of the samples within the production zone(s) where well screen will be installed.
b. Find the finest sediment from the curves. Identify the d_{30} size and determine its size from the grain size chart (in thousands of an inch). Plot that point on the curve.
c. Multiply the d_{30} by a factor of 4 to 6. For fine, well sorted (poorly graded) sand, use a multiplier of 4. Multiply by 6 for coarse, poorly sorted (well graded) sand.
d. Draw a sloping, straight line through the d_{30} point on the graph.
e. Identify the d_{60} and d_{10} sizes on the straight line drawn through the d_{30} point.
f. Calculate the uniformity coefficient. The value should be 2.5 or less. If the value is greater than 2.5, re-draw the straight line through the d_{30} point and re-calculate the uniformity coefficient.
g. Determine the gravel size from the straight-line plot. Gravel packs are typically referred to by sieve sizes, such as 8x16 (read as 8 by 16).

<u>Method No. 2</u>: Simplified Method

Over the years, Roscoe Moss Company (RMC) installed countless gravel packed wells in a wide range of diverse, hydrogeologic settings. RMC, with the assistance and input from various highly experienced consultants, developed a simplified method for gravel pack selection, which is shown on the figure below.



a. Formation Stabilizer
    1) Formations coarser than Line 1 can be stabilized with gravel similar to Gravel A, and 0.094-inch screen.
    2) Formations that plot between Lines 1 and 2 may also be stabilized with Gravel A, and 0.094-inch screen.

b. Filter Pack
    1) Formations finer than Line 2 require a gravel similar to Gravel B, and a 0.060-inch screen.
    2) Gradations 3 and 4 are plots of actual aquifer samples that were successfully constructed with Gravel B and 0.060-inch screen. It should be noted that if the formation is more uniform with the same median size, Gravel B and a 0.060-inch screen would not work. Based on our experience, Gravel B can be modified by addition about 20% finer material (such as a 12x20), and used with 0.060-inch screen.

Summary

With the large number of gravel pack design methods from which to choose, the well designer has many options. Some methods are more straightforward than others, but in the end, most are user-friendly. Therefore, we suggest that one survey the methods, talk to other professionals, select one, and try it. After all, gravel pack design is as much art as it is science. There is no one perfect gravel pack for a particular well. In fact, there is considerable latitude available to the designer that allows for him/her to call upon his/her personal experience in a given area or hydrogeologic setting.

As a final thought, before finalizing a gravel pack design, the designer should consider discussing it with the well drilling contractor. From our own experience, we often accepted a gravel pack design suggested by the contractor. The contractor’s knowledge of the quality and availability of various gravel mixes, and the performance history of other nearby wells drilled by him and others are valuable input that should not be overlooked.

References

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About the Author

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