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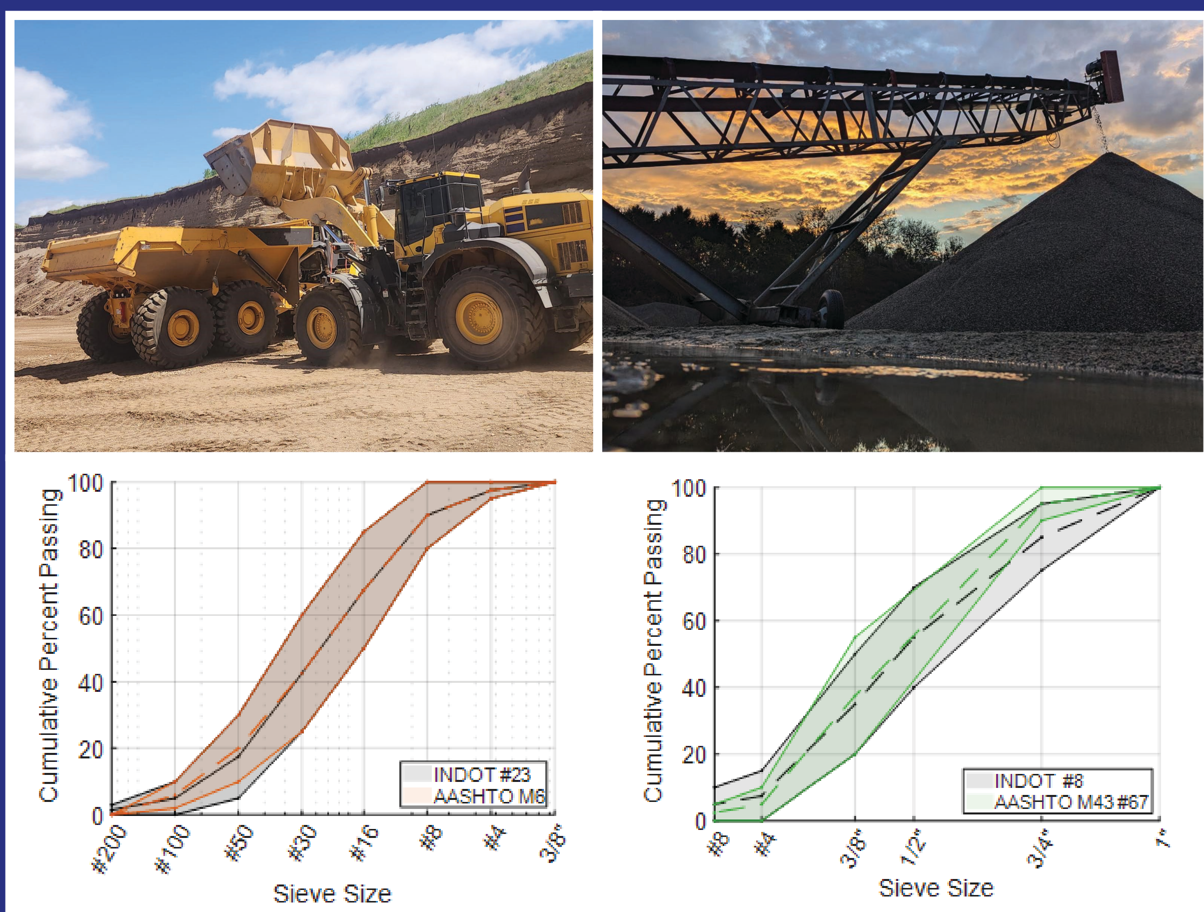
Evaluation of Aggregate Gradation Specifications and the Feasibility of Harmonization With AASHTO Standards



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16. Abstract

The aggregate gradations specified by the Indiana Department of Transportation (INDOT) differ from those of the American Association of State Highway and Transportation Officials (AASHTO). Preliminary discussions suggest that adopting AASHTO standard gradation sizes could provide national alignment and simplify production for those operating in multiple states and supplying projects not subject to INDOT specifications. A comprehensive study was performed to evaluate the current INDOT specifications for coarse and fine aggregate gradations and to assess the potential impacts and feasibility of adopting AASHTO-specified gradations. A comparative analysis of INDOT gradations against AASHTO, ASTM International (ASTM), and those of neighboring states (Ohio, Illinois, Kentucky, and Michigan) was performed. Specifically, the study examined gradations used in concrete, asphalt, and unbound applications. Additionally, surveys and interviews were conducted with industry stakeholders (e.g., producers, contractors, and engineers) in the aggregate, concrete, and asphalt sectors to gain further insight. Results showed that AASHTO offers gradations similar to those currently used by INDOT. Industry stakeholders indicated that transitioning to AASHTO could provide uniform standards with neighboring states and other entities (e.g., ASTM, Federal Aviation Administration), generate economic benefits, improve production consistency, and enhance operational efficiency. Concrete and asphalt stakeholders suggested that adopting these gradations could provide greater flexibility for designing and optimizing mixtures. To shift to aggregate gradations specified by AASHTO, it is advisable to create a comprehensive, multistep plan to reduce disruptions to ongoing projects and the operational processes of industry stakeholders.

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EXECUTIVE SUMMARY

Introduction

The available gradations specified by the Indiana Department of Transportation (INDOT) for fine and coarse aggregates differ from the nationally recognized American Association of State Highway and Transportation Officials (AASHTO) and the ASTM International (ASTM) aggregate gradations. Adopting the national standard gradation sizes could reduce confusion in national communication and simplify aggregate production for entities supplying aggregates to multiple states and projects not subject to INDOT specifications. A comprehensive study was conducted to assess the current INDOT specifications for coarse and fine aggregate gradations and evaluate the potential impacts and feasibility of adopting AASHTO-specified gradations. Specifically, the study examined INDOT gradations used in concrete, hot-mix asphalt (HMA), and unbound (e.g., bases, backfill, and drainage layers) applications and summarized the potential implications of transitioning to AASHTO gradations. Additionally, a comparative analysis was performed between INDOT gradations, ASTM gradations, and the gradation specifications used by neighboring states (Ohio, Illinois, Kentucky, and Michigan).

Findings

It is recommended that INDOT transition from the aggregate gradations currently listed in its Standard Specifications to those specified by AASHTO. Specifically, AASHTO M 43 (road and bridge construction) and M 147 (subbase, base, and surface courses) are recommended for coarse aggregates, and AASHTO M 6 (concrete), M 17 (mineral filler), M 29 (bituminous mixtures), M 45 (masonry mortar), and M 344 (sand seals) for fine aggregates. Additional justification for this transition includes the opportunity to achieve uniform standardization with neighboring states as well as alignment with ASTM, Federal Aviation Administration (FAA), and U.S. Army Corps of Engineers (USACE) specifications. In the long term, the transition is expected to generate economic benefits through improved production consistency and operational efficiency. Aggregate producers operating in multiple states will likely benefit financially due to reduced need for duplicate stockpiles. Since AASHTO gradations more closely resemble those used in neighboring states and ASTM standards, both concrete and HMA producers believe that adopting these gradations would promote greater uniformity and simplify production for suppliers working across state lines or on commercial and FAA projects. Concrete producers also favor AASHTO gradations because they provide greater flexibility for designing and optimizing concrete mixtures. To support the effective implementation of AASHTO gradations, further research is recommended to evaluate their impacts on INDOT-specific HMA and concrete mixtures and to identify any necessary specification adjustments. Additional collaboration with HMA producers will also be important to assess potential implications for aggregate blending requirements.

Implementation

To effectively transition from current INDOT aggregate gradations to those specified by AASHTO, it is recommended to develop well-structured, multistep plan to minimize the disruption to ongoing projects and the operation processes of the industry stakeholders. The proposed plan may include the following:

1. Specification Revision and Adoption

   INDOT should initiate a formal update of its Standard Specifications to replace existing aggregate gradations with those defined in AASHTO standards. Specifically, AASHTO M 43 and M 147 should be adopted for coarse aggregates and AASHTO M 6, M17, M 29, M 45, and M 344 for fine aggregates. During this process, INDOT should clearly document any exceptions, transitional provisions, or project-specific considerations to ensure clarity and consistency in application.

   A transition period (e.g., 12–24 months) should be established to allow aggregate producers, contractors, and material suppliers to adjust their operations. During this phase, both INDOT and AASHTO gradations may be permitted, giving stakeholders sufficient time to modify production processes, deplete existing stockpiles, and align quality control practices with the new requirements.

2. Stakeholder Engagement and Coordination

   Successful implementation will require active engagement with key stakeholders, including aggregate producers, contractors, and materials engineers. INDOT should organize workshops and technical meetings to communicate the rationale, benefits, and technical implications of the transition. Special emphasis should be placed on coordination with HMA producers to evaluate implications for aggregate blending and mix design practices.

3. Pilot Projects and Validation

   Prior to full-scale implementation, it is recommended for INDOT to conduct pilot projects incorporating AASHTO gradations in concrete, HMA, and unbound applications. These projects will help validate performance, identify potential challenges, and inform any necessary refinements to specifications, mix designs, or construction practices.

4. Research and Specification Calibration

   Additional targeted research is recommended to assess the implications of AASHTO gradations on INDOT-specific mixture designs. This may include:

   - Optimization of concrete mixtures to leverage increased flexibility in gradation

- Evaluation of HMA performance and adjustments to aggregate blending practices
- Assessment of unbound material behavior, particularly for drainage and base applications

Close collaboration with HMA producers and concrete suppliers will be essential to ensure that specification updates reflect practical production considerations.

5. Industry Transition and Training

   INDOT should update its quality assurance and quality control (QA/QC) procedures to align with AASHTO gradations. Training programs should be developed for INDOT personnel and industry stakeholders to ensure proper understanding of the new standards, testing methods, and acceptance criteria.

CONTENTS

1. OVERVIEW OF AGGREGATE GRADATIONS AND THEIR USES . . . 10
   1.1 Introduction and Background . . . 10
   1.2 Aggregate Gradations in Concrete Mixtures . . . 10
   1.3 Aggregate Gradations in HMA Mixtures . . . 11
   1.4 Aggregate Gradations in Unbound Applications . . . 12
   1.5 Research Objectives . . . 13
2. COMPARISON OF INDOT AND AASHTO COARSE AGGREGATE GRADATIONS . . . 13
   2.1 INDOT #8 Coarse Aggregate Gradations . . . 14
   2.2 INDOT #11/SC11 and #SC16 Coarse Aggregate Gradations . . . 14
   2.3 INDOT #9 and #12/SC12 Coarse Aggregate Gradations . . . 15
   2.4 INDOT #2 and #5 Coarse Aggregate Gradations . . . 16
   2.5 INDOT #53 and #73 Coarse Aggregate Gradations . . . 16
   2.6 INDOT Precast/Cast-In-Place Concrete Aggregate Size Requirements . . . 17
3. COMPARISON OF INDOT AND AASHTO FINE AGGREGATE GRADATIONS . . . 17
   3.1 INDOT #23 and #24 Fine Aggregate Gradation . . . 17
   3.2 INDOT #15, #16, and PP Fine Aggregate Gradation . . . 18
4. NEIGHBORING STATES CROSS-ANALYSIS WITH INDOT AND AASHTO . . . 19
   4.1 Review of Coarse Aggregate Gradations . . . 19
   4.2 Review of Fine Aggregate Gradations . . . 20
5. SURVEY AND INTERVIEW RESULTS . . . 20
   5.1 Survey Results . . . 20
      5.1.1 Aggregate Producers Survey Results . . . 20
      5.1.2 Concrete Industry Stakeholders Survey Results . . . 22
      5.1.3 HMA Industry Stakeholders Survey Results . . . 23
   5.2 Interview Results . . . 24
      5.2.1 Aggregate Producers Interview Results . . . 24
      5.2.2 Concrete Industry Stakeholders Interview Results . . . 25
      5.2.3 HMA Industry Stakeholders Interview Results . . . 26
6. SUMMARY OF FINDINGS . . . 26
   6.1 Conclusions . . . 26
   6.2 Recommendations . . . 27
   6.3 Future Work . . . 27

REFERENCES . . . 28

APPENDICES . . . 30
   Appendix A. List of Acronyms . . . 30
   Appendix B. INDOT Coarse Aggregate Gradation Summary of Application . . . 30
   Appendix C. INDOT Fine Aggregate Gradation Summary of Application . . . 30
   Appendix D. Aggregate Producers Survey Responses . . . 30
   Appendix E. Concrete Industry Stakeholders Survey Responses . . . 30
   Appendix F. HMA Industry Stakeholders Survey Responses . . . 30

LIST OF TABLES

Table 2.1 Coarse Aggregate Gradation Requirements for INDOT-Specified Structural Concrete Mixtures (INDOT, 2024). 17

Table 3.1 Summary of AASHTO Specifications for Fine Gradations. 17

Table 4.1 Coarse Aggregate Comparison of AASHTO With IN, IL MI, KY, OH, and ASTM. 19

Table 4.2 Fine Aggregate Comparison of AASHTO With IN, IL, MI, KY, and OH. 20

LIST OF FIGURES

Figure 1.1	Tarantula Curve Tool for Optimization of Aggregate Gradations in Concrete Mixtures (Beltran, 2024).	10
Figure 1.2	Shilstone Workability and Coarseness Factor Chart (Ley & Cook, n.d.; Shilstone, 1990).	11
Figure 1.3	Power 0.45 Chart Used for Aggregate Gradation Optimization for HMA Mixtures (FHWA, 2001).	12
Figure 2.1	AASHTO M 43 Comparison Aggregate Gradations Containing Double Digits: (a) 6/67 and (b) 8/89 (AASHTO, 2005; INDOT, 2024).	14
Figure 2.2	INDOT #8 Comparison With (a) AASHTO M 43 #57 and (b) AASHTO M 43 #67 (AASHTO, 2005; INDOT, 2024).	14
Figure 2.3	(a) INDOT #11/SC11 Comparison With AASHTO M 43 #8 and (b) INDOT #SC16 Comparison With AASHTO M 43 #89 (AASHTO, 2005; INDOT, 2024).	15
Figure 2.4	(a) INDOT #9 Comparison With AASHTO M 43 #7 and (b) INDOT #12/SC12 Comparison With AASHTO M 43 #89 (AASHTO, 2005; INDOT, 2024).	15
Figure 2.5	(a) INDOT #2 Comparison With AASHTO M 43 #3 and (b) INDOT #5 Comparison With AASHTO M 43 #57 (AASHTO, 2005; INDOT, 2024).	16
Figure 2.6	(a) INDOT #53 Comparison With AASHTO M 147 Grade B and (b) INDOT #73 Comparison With AASHTO M 147 Grade B (AASHTO, 2022a; INDOT, 2024).	16
Figure 3.1	Fine Aggregate Gradation Comparison of INDOT #23 and INDOT #24 (INDOT, 2024).	18
Figure 3.2	Fine Aggregate Gradation Comparison of (a) INDOT #23 (INDOT, 2024) With AASHTO M 6 (AASHTO, 2013) and (b) INDOT #24 (INDOT, 2024) With AASHTO M 29 #1 (AASHTO, 2012).	18
Figure 3.3	(a) INDOT #15 Comparison With AASHTO M 45-NS and (b) INDOT PP Comparison With AASHTO M 45-NS (AASHTO, 2019).	18
Figure 3.4	INDOT #16 Comparison With AASHTO M 17 (AASHTO, 2019; INDOT, 2024).	19
Figure 4.1	Fine Aggregate Gradation Comparison of AASHTO M 6 (AASHTO, 2013) and ASTM C33 (ASTM, 2023).	20
Figure 5.1	Aggregate Producer Survey Results for Question 1: "Are there any general difficulties with having to switch between INDOT and AASHTO/ASTM/Other agency gradations?"	21
Figure 5.2	Aggregate Producer Survey Results for Question 9.2: "Are AASHTO gradations more favorable for aggregate producers that operate in multiple states?"	21
Figure 5.3	Aggregate Producer Survey Results for Question 2.3: "From a manufacturing perspective, which gradation is more practical to produce?"	21
Figure 5.4	Aggregate Producer Survey Results for Question 9: "Overall, from a producer's perspective, what would the reaction be if INDOT adopted AASHTO gradations?"	21
Figure 5.5	Concrete Industry Stakeholders Survey Results for Question 1: "DOTs in states like Ohio and Kentucky use AASHTO or ASTM gradations, while Michigan and Illinois follow their own state-specific standards. Other specifiers, such as the FAA or commercial clients, may also require unique gradations. In your opinion, how do these alternative gradations compare to INDOT's standard gradations for concrete production or base/backfill applications?"	22
Figure 5.6	Concrete Industry Stakeholders Survey Results for Question 2: "Do you have a preference between using INDOT gradations and those specified by other agencies (e.g., AASHTO, ASTM, FAA, or state/commercial specifications)?"	22
Figure 5.7	Concrete Industry Stakeholders Survey Results for Question 6: "Overall, would you benefit from or be hurt by a change from INDOT's standard gradations to AASHTO or ASTM gradations?"	23

Figure 5.8 HMA Industry Stakeholders Survey Results for Question 1: "DOTs in states like Ohio and Kentucky use AASHTO or ASTM gradations, while Michigan and Illinois follow their own state-specific standards. Other specifiers, such as the FAA or commercial clients, may also require unique gradations. In your opinion, how do these alternative gradations compare to INDOT's standard gradations for concrete production or base/backfill applications?" 23

Figure 5.9 HMA Industry Stakeholders Survey Results for Question 2: "Do you have a preference between using INDOT gradations and those specified by other agencies (e.g., AASHTO, ASTM, FAA, or state/commercial specifications)?" 24

Figure 5.10 HMA Industry Stakeholders Survey Results for Question 6: "Overall, would you benefit from or be hurt by a change from INDOT's standard gradations to AASHTO or ASTM gradations?" 24

1. OVERVIEW OF AGGREGATE GRADATIONS AND THEIR USES

1.1 Introduction and Background

Aggregate materials are used in a wide range of transportation-related applications, including concrete and bituminous mixtures, unbound base and subbase layers, structural backfill, drainage systems, and riprap. In bound applications such as concrete and asphalt mixtures, aggregates (both coarse and fine) form the primary structural skeleton, while Portland cement or asphalt binder (along with any necessary additives) bind the particles together to achieve the desired mechanical and durability properties. In unbound applications (e.g., bases, backfill, and drainage layers), aggregate gradation plays a critical role in governing packing, stability, permeability, and load transfer. Similarly, in erosion control applications such as riprap, aggregate size distribution is essential for ensuring hydraulic stability and resistance to displacement. To meet performance requirements across these applications, contractors and material producers often blend multiple aggregate sizes, in carefully controlled proportions, to achieve target gradations and corresponding engineering properties. The term "aggregate sizes," as used here, refers to specific gradations of coarse or fine aggregate defined by governing specifications.

Sections 904.02 and 904.03 of the Indiana Department of Transportation (INDOT, 2024) Standard Specifications provide criteria for classifying natural or manufactured aggregates into fine and coarse categories. These criteria include properties such as rock type, specific gravity, elemental magnesium content in dolomite, deleterious constituents (e.g., in steel slag), polish resistance, sulfate soundness, angularity, particle size distribution, and gradation. Among these, gradation requirements specified by INDOT differ from nationally recognized classification systems such as American Association of State Highway and Transportation Officials (AASHTO, 2005, 2012, 2013, 2016, 2017, 2019, 2022b, 2022c) and ASTM International (ASTM, 2022, 2024), particularly with respect to standardized aggregate size designations for transportation and infrastructure applications.

The potential benefits of adopting nationally recognized gradation sizes (e.g., AASHTO) would improve consistency in communication, streamline the use of existing technical resources, and reduce confusion and cost. Additional benefits may include potential improvements in concrete and HMA quality through aggregate optimization and increased efficiency for aggregate producers supplying multiple states by eliminating the need to adjust production to different gradation systems.

1.2 Aggregate Gradations in Concrete Mixtures

The total aggregate volume typically constitutes 60–75% of a concrete mixture (Yong et al., 2018), so gradation strongly affects both the workability of fresh concrete and the strength and durability of hardened concrete (Kosmatka & Wilson, 2011). Concrete mixtures produced in Indiana primarily use an aggregate blend of INDOT #8 coarse aggregate and INDOT #23 fine aggregate, and often INDOT #11 as an intermediate aggregate (INDOT, 2024).

In addition to improving performance, optimizing aggregate gradation can provide economic benefits by reducing material waste and extending service life. Poor gradation can result in low-quality concrete, whereas well-graded aggregates enhance particle packing, reduce voids, and strengthen the concrete microstructure (Kosmatka & Wilson, 2011). Fewer voids lower the amount of paste required, which reduces the risk of autogenous during hydration. Better particle packing also stiffens the microstructure, increasing resistance to internal stresses from drying shrinkage and other durability issues (Gross et al., 2022; Hahn Ready Mix, 2023).

Using an optimized gradation that densifies particle packing can also increase the compressive strength of concrete without increasing the cement content (Schlorholtz et al., 2006). Incorporating intermediate aggregates further improves packing and can enhance strength (Ley et al., 2012). However, designers must balance gradation to maintain desirable fresh properties, such as workability and resistance to segregation (Gross et al., 2022). Gradations that are too fine increase particle surface area, raising water demand and making the concrete stickier and harder to finish (Gross et al., 2022; Hahn Ready Mix, 2023; Kosmatka & Wilson, 2011). Gradations that are too coarse reduce edge stability and make consolidation difficult, which can lead to segregation and inadequate flow during placement (Ley et al., 2012).

As discussed above, optimizing aggregate gradation reduces the amount of paste needed to fill voids and minimizes the risk of paste being trapped between particles, freeing more paste to act as a lubricant. This improves concrete workability by decreasing particle-to-particle friction (Gross et al., 2022; Hahn Ready Mix, 2023; Schlorholtz et al., 2006). Various tools are available to help designers achieve target performance while minimizing cement paste content. For example, the Tarantula curve (Figure 1.1) provides recommended limits for each sieve size and is commonly used to proportion combined aggregate gradations in concrete pavement mixtures (Ley & Cook, n.d.). By following such guidelines, designers can optimize aggregate

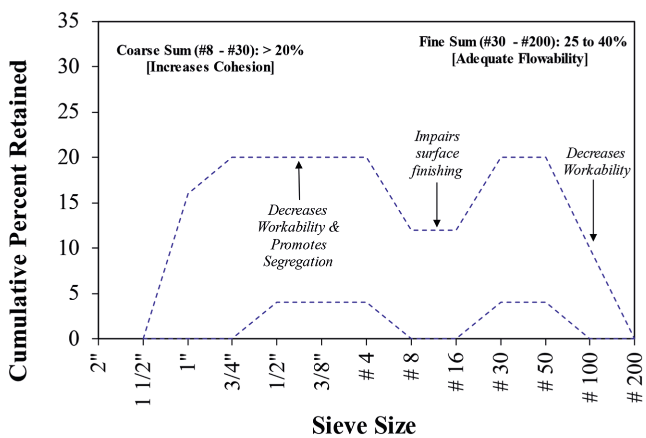


Figure 1.1 Tarantula Curve Tool for Optimization of Aggregate Gradations in Concrete Mixtures (Beltran, 2024).

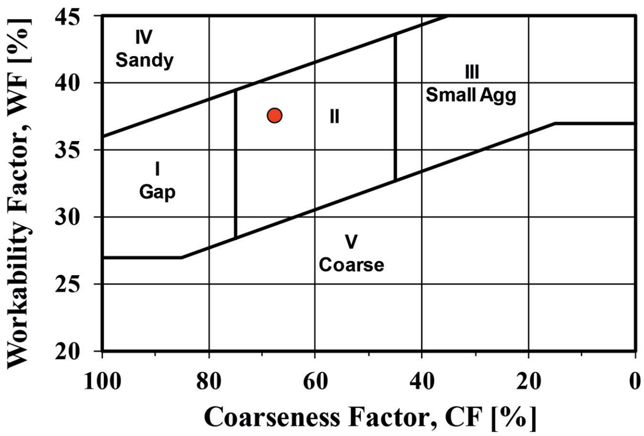


Figure 1.2 Shilstone Workability and Coarseness Factor Chart (Ley & Cook, n.d.; Shilstone, 1990).

gradation to produce concrete mixes that meet performance requirements while controlling paste content.

The Shilstone chart is another graphical tool used to optimize the combined aggregate gradation in concrete mixtures (Figure 1.2). By plotting the coarseness factor (CF) and workability factor (WF) for a given gradation, designers can predict concrete workability (Hahn Ready Mix, 2023; Ley & Cook, n.d.; Shilstone, 1990). The Shilstone chart serves as a reliable guide for optimizing aggregate gradation in concrete mixes, forecasting edge stability, and evaluating the contribution of intermediate aggregates to strength.

The Shilstone chart consists of five regions, each indicating the properties of a specific combined aggregate gradation (Hahn Ready Mix, 2023; Ley & Cook, n.d.; Shilstone, 1990):

- **Region I**: Gap-graded mixtures with high coarse aggregate content, which can be prone to segregation during placement.
- **Region II**: Well-graded mixtures; this is the target zone for achieving adequate workability.
- **Region III**: Slightly higher fine content than Region II; moderately desirable.
- **Region IV**: Gradations that are too fine, increasing the risk of segregation and reducing compressive strength; this region should be avoided.
- **Region V**: Gradations that are overly coarse (“rocky”) and unsuitable for optimized concrete.

For example, a previous study applied the Shilstone chart to predict concrete performance (Ley et al., 2012). Mixtures with a 60/40 aggregate blend positioned near the center of Region II required less water-reducing admixture (WRA) to achieve proper vibration during placement. This demonstrates that optimizing aggregate gradation with tools like the Shilstone chart can improve workability while minimizing reliance on WRAs (Ley et al., 2012).

Overall, properly optimizing aggregate gradation in concrete is essential, as inadequate gradation can initiate a chain of interrelated negative effects that threaten workability, durability, and sustainability, ultimately compromising overall material performance.

1.3 Aggregate Gradations in HMA Mixtures

Aggregate gradation is an important component in the design of hot-mix asphalt (HMA) mixtures, influencing numerous performance categories (Kandhal & Cooley, 2001; Roberts et al., 1996). In the state of Indiana, the most commonly used coarse aggregate gradations for HMA mixtures are INDOT #8, 11/SC11, 12/SC12, and SC16 (INDOT, 2024). The letters “SC” refer to their use in seal coat applications. However, HMA producers in Indiana prefer to use quality assurance (QA) products instead, which offer more desirable gradations than INDOT listed gradations. These QA products are set by HMA producers with the approval from INDOT Certified Aggregate Producer Program (CAPP; INDOT, 2023). HMA producers often find INDOT gradation limits strict, limiting the ability to produce certain gradations and making it difficult to control fines. Conversely, AASHTO M 43 provides a broader range of coarse aggregate gradations (AASHTO, 2005). Additionally, INDOT offers only two fine aggregate gradations (#23 and #24), whereas AASHTO M 29, specifically intended for use in asphalt mixtures, offers five gradations (AASHTO, 2012).

Several performance criteria are influenced by the volumetric properties in HMA mixtures, which are influenced by the aggregate blend and gradation (Asphalt Institute, 2014; Roberts et al., 1996). Important volumetric properties when designing HMA mixtures include air void content, voids in mineral aggregates (VMA), voids filled with asphalt (VFA), and dust-to-binder ratio. These are key parameters that help control compaction and durability of HMA. Designing for optimal volumetric properties is essential in managing the performance of a mixture and achieving balanced compaction, durability, and strength.

The VMA controls the amount of binder that is incorporated in the aggregate structure for an HMA mixture (Asphalt Institute, 2014; National Cooperative Highway Research Program, 2011; Roberts et al., 1996). Designing for optimal VMA results in a mixture with a binder film thickness that enhances durability and fatigue resistance. Therefore, HMA mixtures with insufficient VMA can reduce fatigue resistance and durability. The voids filled with asphalt (VFA) represent the amount of VMA occupied by binder and directly correlate with mastic richness and stiffness. A higher VFA indicates a greater amount of binder content filling the voids of the aggregate structure, which improves durability (Asphalt Institute, 2014; National Cooperative Highway Research Program, 2011; Roberts et al., 1996). However, if VFA is too high, it may reduce rutting resistance by creating a mastic that is too soft. While a lower VFA results in a stiffer mastic, which can enhance rutting resistance but decrease durability and fatigue resistance, due to insufficient binder within the aggregate structure of an HMA mixture.

Air void content is an important characteristic of HMA mixtures that controls compaction and durability, which is interrelated with VMA (Asphalt Institute, 2014; Roberts et al., 1996). Having a lower air content can reduce stability and rutting resistance, while a higher air content increases permeability and compromises durability (AASHTO, 2022c; Advanced Asphalt Technologies, 2011). The dust-to-binder ratio controls the fines content of an HMA mixture, which influences mastic stiffness, compaction, and durability. Decreasing the dust-to-binder ratio results in a mastic that is too soft, leading to reduced stability, rutting resistance, and moisture susceptibility. While increasing results in an HMA with a mastic that is too stiff and tender, causing poor compaction.

The performance of HMA is enhanced by an optimized gradation blend, as it influences air content, VMA, and the dust-to-binder ratio, providing stability against traffic, temperature, and deterioration (Federal Highway Administration [FHWA], 2001, 2022; Kandhal & Cooley, 2001; Roberts et al., 1996). Coarser gradations can improve stability and rutting resistance by increasing stone-to-stone contact. Finer gradations can improve HMA placement by enhancing workability and compaction (Kandhal & Cooley, 2001). Proper placement is key to achieving high performance with HMA. However, excessive fines can cause tender mixtures, compaction sensitivity, increased traffic-induced rutting risk, and increased moisture susceptibility (Asphalt Institute, 2014; Advanced Asphalt Technologies, 2011). Conversely, low fines result in poor mastic, increased permeability, and a higher risk of raveling. Hence, controlling the coarseness and fineness of an aggregate gradation is crucial (FHWA, 2001). These limited examples of the proportioning of an aggregate blend illustrate the importance of an optimized gradation that meets the numerous requirements for durability and placement to produce high-quality HMA.

HMA performance can be enhanced by selecting an appropriate gradation based on desired characteristics. The four main gradation types often used in asphalt mixtures include dense-graded, open-graded, gap-graded, and nominal maximum aggregate size (NMAS). Dense-graded is the most commonly used gradation type, providing a well-distributed gradation from coarse to fine aggregates (FHWA, 2002; Pavement Interactive, n.d.b; Roberts et al., 1996). Selected for HMA mixtures used for pavements, specifically for the surface, intermediate, and base layers. Offering a balanced performance across different categories with adequate performance in durability, workability, and strength. Gap-graded is another gradation type that excludes intermediate sieve sizes, resulting in a coarser gradation (FHWA, 2002; Pavement Interactive, n.d.b; Roberts et al., 1996). Typically, gap gradations are used primarily for stone matrix asphalt (SMA), as well as HMA, to enhance rutting resistance. However, gap-graded aggregate requires more binder in HMA mixtures, potentially resulting in financial and performance implications. Additionally, when gradation is gap-graded, this can compromise moisture susceptibility by allowing moisture to be more easily trapped and weakening adhesion. An open-graded gradation has a low fines content and is typically used to improve surface friction, noise control, and drainage in HMA pavements (Asphalt Institute, 2014). They have limited use in HMA mixtures because they produce high air-void content, resulting in lower strength and increased clogging. NMAS is a gradation with a defined control sieve, designed to target a desired VMA, binder content, and performance, which is especially used in the Superpave design method (AASHTO, 2022c; FHWA, 2001; Roberts et al., 1996). Each of the listed gradation types offers advantages and disadvantages, with interrelated effects on the proportions of components in HMA mixtures and

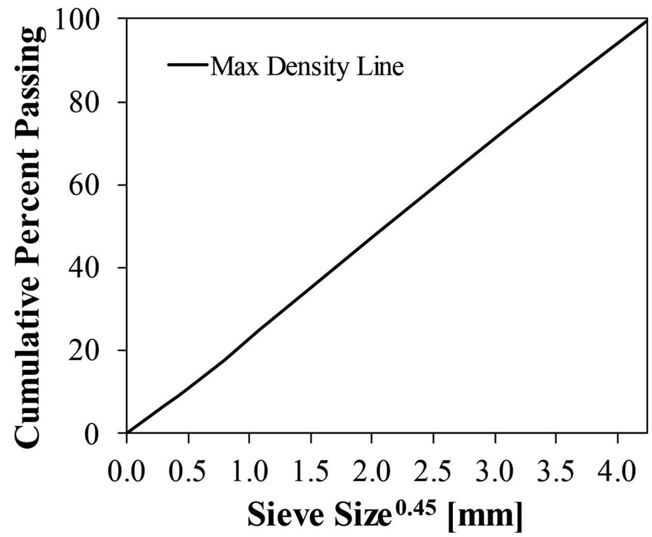


Figure 1.3 Power 0.45 Chart Used for Aggregate Gradation Optimization for HMA Mixtures (FHWA, 2001).

performance. Hence, highlighting the importance of selecting and optimizing aggregate gradation and blend proportions.

Several optimization methods assist designers in producing high-quality HMA mixtures with desired performance traits by optimizing aggregate gradation and blend. A commonly used design method is Superpave, an HMA mixture design method adopted by AASHTO and several states (AASHTO, 2022c; FHWA, 2001; Roberts et al., 1996). This method focuses on two main components: selecting the binder and the aggregate structure, which are used to create a mixture through volumetric design using air voids, VMA, VFA, and binder content. Importantly, in selecting the aggregate structure, the blend and gradation are crucial for controlling volumetric properties to achieve the target mixture. This is achieved using gradation tools such as the 0.45 power chart (Figure 1.3), which defines control points at critical sieve sizes with allowable limits to prevent extreme gradations and ensure workable blends. Additionally, defining a nominal maximum aggregate size is vital, as it influences binder content to ensure adequate VMA.

1.4 Aggregate Gradations in Unbound Applications

Aggregates are a widely used material for unbound applications in backfill, drainage, and erosion control. For these applications, the aggregate size and gradation are key properties for ensuring adequate performance. In erosion control applications, such as riprap, aggregate size and gradation are crucial for maintaining stability and preventing displacement. In unbound drainage applications, gradation is a primary determinant of drainage performance. The performance criteria are governed by how these unbound aggregate applications are used. Since gradation can achieve this, INDOT lists various aggregate sizes as options for these unbound applications (Adams et al., 2024; INDOT, 2024; Tutumluer, 2013). In pavement applications, aggregates are also used in the subsurface layers (e.g., base and subbase) of Portland cement concrete (PCC) and HMA pavements. Depending on the pavement type, the subsurface layers (number and depth) and their functions vary. Depending on the function of the subsurface layer, the selection of aggregate gradation is crucial to meeting specific design requirements. Layers that prioritize mechanical performance prefer a dense-graded aggregate for its ability to reduce voids and improve packing, thereby limiting erosion and improving pavement stability. For applications that prioritize drainage, designers often aim for a more open-graded aggregate to increase permeability. Regardless, both pavement stability and drainage are important functions for subsurface layers, and selecting an aggregate gradation that provides both is crucial. Aside from PCC and HMA pavements, aggregate pavements composed of a dense-graded aggregate (INDOT #53 or #73) surface layer and a base layer composed of a coarser aggregate (INDOT #2, #5, or #8) are also commonly used. Depending on the desired mechanical and drainage performance of the aggregate pavement, the listed gradation selections will vary (Adams et al., 2024; INDOT, 2024; Tutumluer, 2013).

PCC pavements typically include only a subbase/base layer beneath the PCC surface layer. In a typical PCC pavement design for Indiana, the concrete pavement layer is 9 to 14 in. in depth. Since PCC, as a material, offers sufficient mechanical performance (especially at these thicknesses), it can support load transfer and pavement stability. Therefore, PCC pavements are less reliant on the base layer for mechanical performance, but still reliant on it for uniform support of the surface layer. A combination of subgrade (treated) and the overlying base/sub-base layers provide a good foundation for the pavement structure as a whole. Water penetrates the underlying layers since PCC is a highly permeable material; hence, an essential function of the base layer is drainage, along with underdrains placed along the edges of the pavement. A typical PCC pavement design in Indiana, composed of a 4 to 6-in. dense-graded aggregate (INDOT #53 or #73) base layer for uniform support of the PCC surface layer, and a 3 to 6-in. open-graded aggregate (INDOT #8) for drainage (Hein et al., 2017; INDOT, 2024).

Typical HMA pavements in Indiana are designed to have the following layers: (i) surface course, (ii) binder course, (iii) base course, (iv) subbase, and (v) subgrade. In contrast, HMA pavements have a much thinner surface course (1 to 2 in. thick) and an underlying intermediate or binder course (1.5 to 3.5 in. thick) resting on a base course. They are designed with additional subsurface layers and rely heavily on them for mechanical performance and pavement stability. Since water is detrimental to HMA (can cause stripping), a function of the surface layer is to prevent water from entering the subsurface layers, meaning the subsurface layers do not need to prioritize drainage as much. The base layer is typically 6 to 12 in. thick and dense-graded (INDOT #53). Its primary function is to provide uniform support for the HMA layers, distribute traffic loads, and ensure pavement stability. In some applications, a dense-graded (INDOT #53) aggregate subbase layer is included for additional support (INDOT, 2024; Pavement Interactive, n.d.a, n.d.b; Roberts et al., 1996).

1.5 Research Objectives

A comprehensive study was conducted to assess current INDOT specifications for aggregate gradations and evaluate the potential effects of aligning with the AASHTO/ASTM standards. The goal of this study is to determine whether INDOT can replace its existing aggregate gradations with AASHTO gradations. Effects on aggregate producers and INDOT construction requirements will be examined to assess feasibility. In this study, INDOT gradations specified for concrete and HMA uses were analyzed, and the potential impacts were summarized. This analysis covered both coarse and fine aggregate gradations. A comparison of INDOT gradations with AASHTO gradations was performed to evaluate similarities and differences. Additionally, the gradations of neighboring states (Ohio, Illinois, Kentucky, and Michigan) were reviewed and compared with INDOT and AASHTO aggregate gradations (Illinois Department of Transportation [IDOT], 2022; Kentucky Transportation Cabinet [KYTC], 2019; Michigan Department of Transportation [MDOT], 2020; Ohio Department of Transportation [ODOT], 2023). To gauge industry stakeholder consensus, including aggregate producers, concrete producers/contractors, and HMA producers/contractors—survey questionnaires were distributed to key stakeholders, along with follow-up interviews.

2. COMPARISON OF INDOT AND AASHTO COARSE AGGREGATE GRADATIONS

Coarse aggregate gradations specified by AASHTO use both single- and double-digit numeric designations to indicate their sizes. For single-digit gradations, smaller numbers denote coarser aggregates, typically used for base courses or cases that require higher strength or load-bearing capacity. Larger numbers indicate finer aggregates, usually used for concrete, HMA, or drainage. AASHTO also includes double-digit gradation numbers, which represent a combination of two aggregate gradations; however, this practice is not used by INDOT. INDOT gradations employ a numeric system where lower numbers correspond to coarser aggregates, regardless of whether it is single or double digit. Additionally, INDOT uses the alphabetical designations SC (seal coat) and PG (pea gravel) to further identify gradation numbers (INDOT, 2023, 2024, 2025).

AASHTO has two standard specifications for coarse aggregate gradations: (i) M 43 and (ii) M 147. AASHTO M 43 specifies coarse aggregate gradations for road and bridge construction and includes a total of 19 gradations. AASHTO M 147 specifies coarse aggregate gradations for subbase, base, and surface courses, and comprises a total of five gradations. In Section 904.03 of INDOT standard specifications, a total of 12 coarse aggregate gradations are specified. These gradations are used for various road and bridge construction purposes and share some similarities with the gradations in AASHTO M 43 and M 147 (AASHTO, 2005, 2017).

Additionally, it should be noted that section 904.03 of the INDOT (2024) standard specifications states, "Where an AASHTO coarse aggregate is specified as an option, gradation shall be in accordance with AASHTO M 43. All other aggregate properties shall be in accordance with 904." It is also important to note that Section 904.05 of the INDOT standard specifications includes five gradations for structural backfill. However, for the purposes of this study, these gradations were not examined.

By examining the gradations of AASHTO, when a second digit is added to an existing gradation (e.g., #6 to #67, #8 to #89), the coarse portion remains roughly the same, but the double-digit gradation becomes finer. This occurs because of the increased cumulative percentage passing in the finer portion, and the inclusion of an additional smaller sieve (Figure 2.1).

Out of the twelve INDOT coarse aggregate gradations listed in 904.03, only one (#93PG) does not resemble any AASHTO gradations specified in M 43 and M 147. However, INDOT #93PG is explicitly specified only once for construction (INDOT 731.05) and primarily serves to blend aggregates and other miscellaneous applications that do not have specific requirements.

2.1 INDOT #8 Coarse Aggregate Gradations

Typically, for concrete applications, INDOT #8 aggregate gradation is used, which is similar to AASHTO M 43 #57 and #67. However, INDOT #8 allows a slightly higher percentage passing the 3/4-in. sieve than AASHTO #67 (see Figure 2.2b). Despite this difference, INDOT #8 closely aligns with AASHTO #67, since both share nearly identical bounds at all other sieve sizes. In contrast, AASHTO #57 includes an extra 1 1/2-in. sieve and a lower percent passing across all sieves, resulting in a coarser gradation than INDOT #8 (see Figure 2.2a).

Additionally, INDOT currently has the specifications, Indiana Test Method (ITM) 226, which allows concrete mixtures to use AASHTO M 43 #57 as a coarser gradation alternative to INDOT #8. However, ITM 226 is rarely used, mainly because aggregate producers in Indiana generally do not produce AASHTO M 43 #57. As a result, concrete producers cannot design using this gradation due to its low availability. In areas of Indiana near Ohio and Kentucky, aggregate producers are more likely to produce AASHTO M 43 #57, since the aggregate gradations in those states align with AASHTO.

2.2 INDOT #11/SC11 and #SC16 Coarse Aggregate Gradations

When analyzing the coarse aggregate gradations used for HMA applications, only INDOT #11/SC11 (Figure 2.3a) and INDOT #SC16 (Figure 2.3b) have gradations that are similar to those listed in AASHTO M 43. AASHTO M 43 #8 closely resembles INDOT #11/SC11, except it has a higher percentage passing the 3/8-in. sieve and includes an additional finer sieve (No. 16).

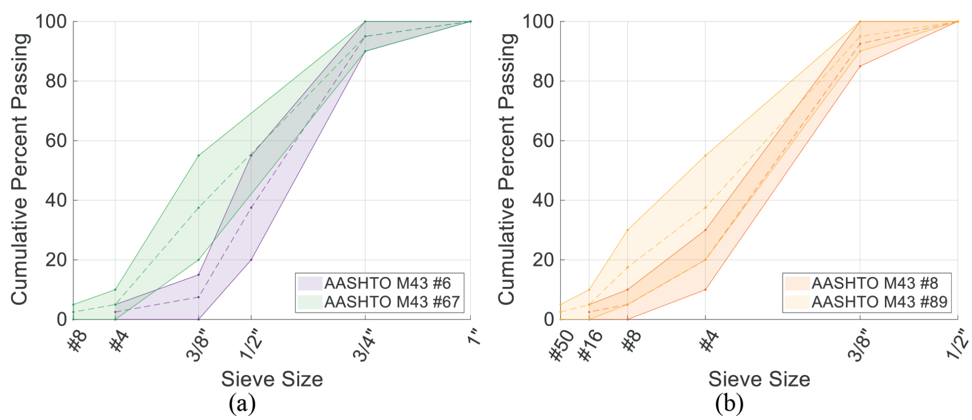


Figure 2.1 AASHTO M 43 Comparison Aggregate Gradations Containing Double Digits: (a) 6/67 and (b) 8/89 (AASHTO, 2005; INDOT, 2024).

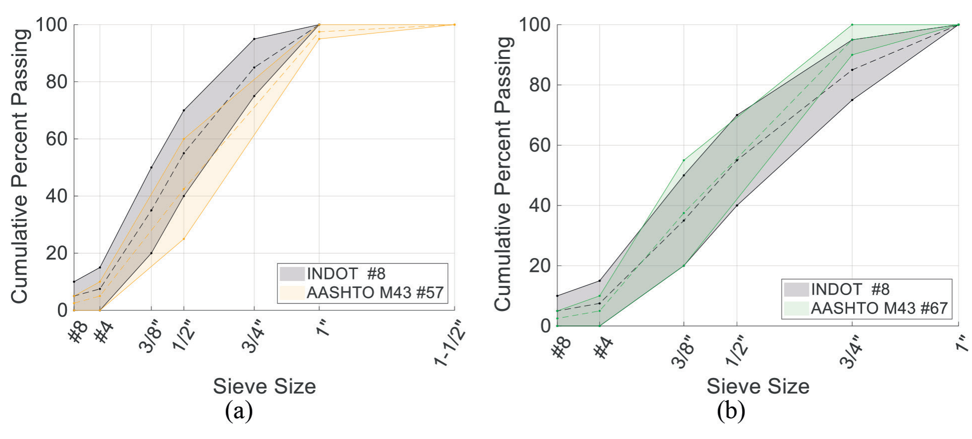


Figure 2.2 INDOT #8 Comparison With (a) AASHTO M 43 #57 and (b) AASHTO M 43 #67 (AASHTO, 2005; INDOT, 2024).

AASHTO #89 most closely matches the gradation of INDOT #SC16, though it has broader limits. Furthermore, AASHTO gradations include the No. 50 sieve, which INDOT does not, and this difference may affect the observed variations. Additionally, INDOT #SC16 is based on IDOT gradation #16. As noted earlier, the "SC" designation in INDOT gradations indicates the aggregate gradation is intended for HMA seal coating.

2.3 INDOT #9 and #12/SC12 Coarse Aggregate Gradations

INDOT #9 serves as a coarse aggregate gradation used for various structural concrete applications. As in the case of INDOT #12/SC12, INDOT #9 does not align well with any AASHTO gradation standards. The closest match is AASHTO M 43 #7, though it shows a significant difference (Figure 2.4a). Specifically, it has a higher percentage passing at the 1/2-in. and 3/8-in. sieves and features tighter gradation limits overall. However, with proper application methods, such as blending or adjusting proportions, it can effectively substitute for INDOT #9.

INDOT #12/SC12 is a coarse aggregate gradation mainly designed for HMA and seal coat applications. Although AASHTO specifications do not specify an exact match, the closest comparable gradation is AASHTO M 43 size #89. Notably, there are substantial differences at the No. 4 sieve, where INDOT #12/SC12 is significantly finer and has a higher percentage passing at each sieve (Figure 2.4b). These variations result in a more interconnected void spaces in INDOT #12/SC12 gradation, facilitating higher VMA in HMA mixtures. This type of open gradation with those specific sieves is not available through AASHTO. Moreover, AASHTO gradations include the No. 50 sieve, which INDOT does not, and unlike AASHTO, INDOT uses the No. 30 sieve. This difference may explain why INDOT #12/SC12 lacks gradations similar to those in AASHTO. However, this may be insignificant, as the No. 30 makes up less than 4% and the No. 50 less than 5%, and both are the smallest sieve sizes used in each gradation.

AASHTO M 43 #89 might negatively affect the VMA of HMA mixtures that currently depend on INDOT #12/SC12. However, blending can increase the amount retained on the No. 4 sieve, allowing the AASHTO M 43 #89 gradation to match the performance of INDOT #12/SC12. Blending is also a common practice among HMA producers, regardless of specific gradation targets. Additionally, HMA mixtures can reach the required VMA by increasing the proportion of AASHTO M 43 #89 to

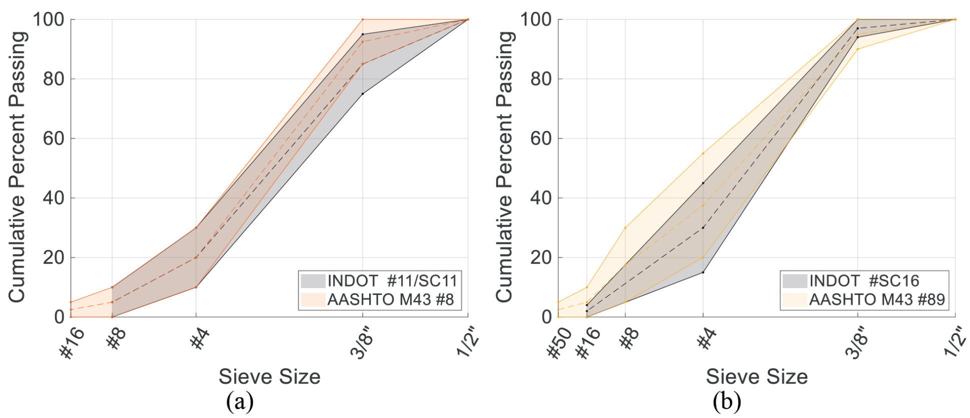


Figure 2.3 (a) INDOT #11/SC11 Comparison With AASHTO M 43 #8 and (b) INDOT #SC16 Comparison With AASHTO M 43 #89 (AASHTO, 2005; INDOT, 2024).

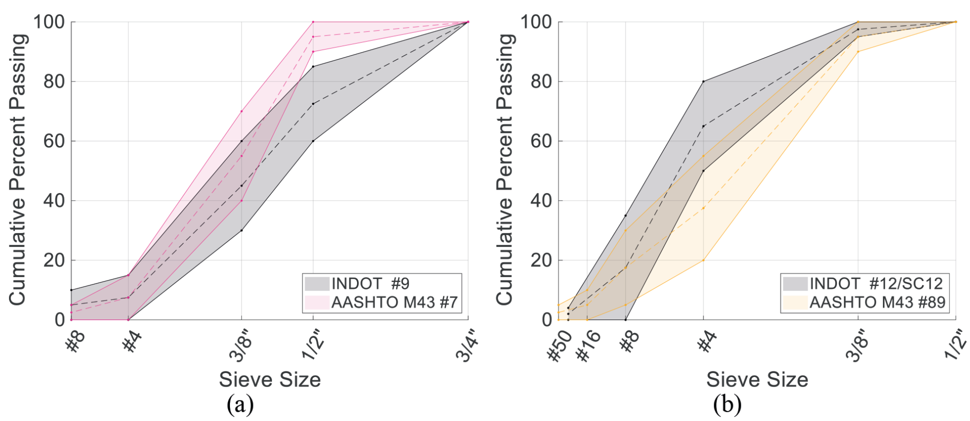


Figure 2.4 (a) INDOT #9 Comparison With AASHTO M 43 #7 and (b) INDOT #12/SC12 Comparison With AASHTO M 43 #89 (AASHTO, 2005; INDOT, 2024).

add more material at the No. 4 sieve. Therefore, concerns about the performance of AASHTO M 43 #89 may be limited, and the more flexible bounds at each sieve could offer greater design options for HMA mixtures.

2.4 INDOT #2 and #5 Coarse Aggregate Gradations

AASHTO M 43 #3 has a gradation similar to INDOT #2 (Figure 2.5a) and is specified by INDOT for various construction unbound applications; however, it is not commonly used for concrete or HMA mixes. Although both gradations follow similar trends, they differ slightly at intermediate sieve sizes. INDOT #2 tends to have a more open gradation, while AASHTO M 43 #3 is well-graded, offering greater flexibility. Specifically, INDOT #2 has a lower percent passing and tighter allowable ranges at the 1-in. sieve, wider ranges at the 1 1/2-in. sieve, and higher percent passing with tighter ranges at the 2-in. sieve.

In Figure 2.5b, the gradation of INDOT #5 appears similar to AASHTO M 43 #57. However, AASHTO M 43 #57 has tighter allowable limits and a lower percent passing at the smallest two sieves (No. 4 and No. 8). They also differ at the 1-in. sieve, with AASHTO M 43 #57 showing tighter bounds and a higher percent passing.

2.5 INDOT #53 and #73 Coarse Aggregate Gradations

INDOT gradations #53 and #73 are dense-graded aggregates used for various unbound applications for pavements (surface, base, subbase), drainage, backfill, and erosion control. Although they do not correspond to any AASHTO M 43 gradations, INDOT #53 aligns most closely with AASHTO M 147 Grade B, and INDOT #73 with Grade C. These were the only INDOT gradations showing similarities to any of the five gradations listed in AASHTO M 147.

As shown in Figure 2.6a, INDOT #53 closely resembles AASHTO M 147 Grade B in its average gradation curve (average of the maximum and minimum allowable limits). However, AASHTO M 147 Grade B allows for a broader range at all sieves and generally permits a lower percent passing. It also includes an additional 2-in. sieve, which further increases the coarseness range, resulting in a coarser gradation than INDOT #53.

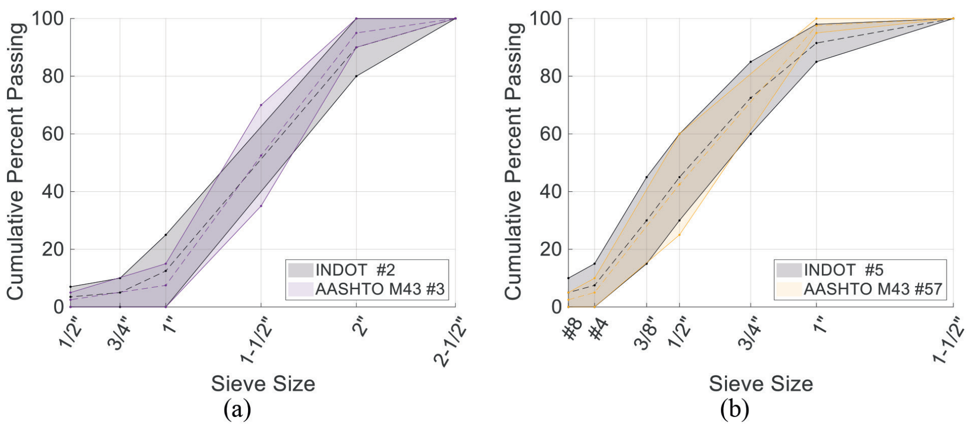


Figure 2.5 (a) INDOT #2 Comparison With AASHTO M 43 #3 and (b) INDOT #5 Comparison With AASHTO M 43 #57 (AASHTO, 2005; INDOT, 2024).

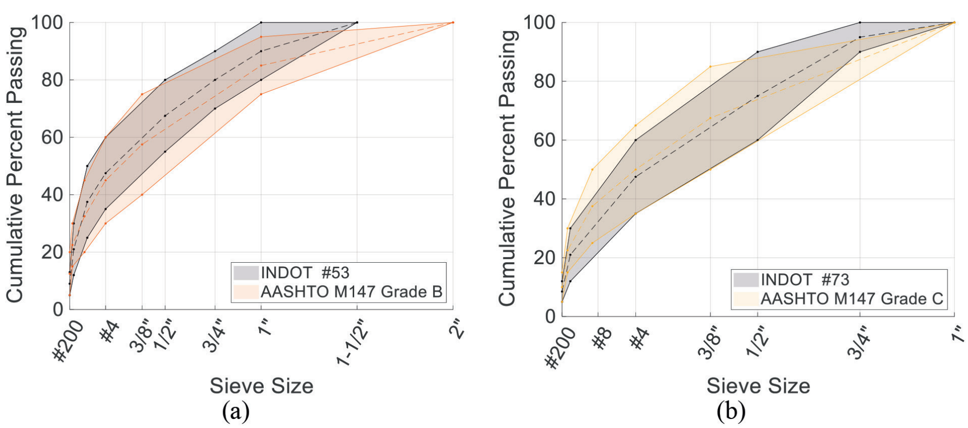


Figure 2.6 (a) INDOT #53 Comparison With AASHTO M 147 Grade B and (b) INDOT #73 Comparison With AASHTO M 147 Grade B (AASHTO, 2022a; INDOT, 2024).

A comparison between INDOT #73 and AASHTO M 147 Grade C in Figure 2.6b reveals a fairly similar alignment. However, AASHTO M 147 Grade C shows a marginally higher percent passing at the finer sieves, from No. 200 to 3/8-in. The two gradations differ partly because INDOT #73 uses a 1/2-in. sieve, while AASHTO M 147 Grade C employs a 3/8-in. sieve. These details suggest that AASHTO M 147 Grade C has a slightly finer gradation, with the finer portion more clearly specified. Additionally, INDOT #73 includes an extra intermediate sieve (3/4-in.), resulting in stricter overall gradation requirements, thus giving AASHTO M 147 Grade C more flexibility.

2.6 INDOT Precast/Cast-In-Place Concrete Aggregate Size Requirements

INDOT #91 does not align with any AASHTO gradations found in M 147 or M 43. It has a loose gradation criterion, requiring only 100% passing the 1-in. sieve. This gradation is mainly used for precast concrete structures (INDOT Standard Specification 700) and was created specifically for this application. Although AASHTO does not provide a gradation with loose requirements comparable to INDOT #91, it does include twelve gradations under M 43 that meet the 100% passing at the 1-in. sieve requirement.

Table 2.1 summarizes the aggregate requirements for the 15 INDOT-specified structural concrete mixtures, each with AASHTO equivalents for coarse and fine aggregates. All mixtures have a fine aggregate requirement of INDOT #23, which aligns strongly with AASHTO M 6. Nonetheless, six of these mixtures limit the coarse aggregate to INDOT #9, 91, or 12. As noted in Section 2.3, the AASHTO gradations corresponding to these three INDOT gradations tend to have weaker alignment compared to other INDOT gradations studied. Consequently, replacing these gradations might require additional blending or adjustments to mixture proportions.

TABLE 2.1
Coarse Aggregate Gradation Requirements for INDOT-Specified Structural Concrete Mixtures (INDOT, 2024).

		Coarse Aggregate Size	
Application	**Section**	**INDOT**	**AASHTO M 43 Equivalent**
Pavement	502.04	#8	#57/#67
Patching Full Depth	506.04	#9	#7/#78
Patching Partial Depth	506.04	#11	#8
CPM or OPCC	509.04	#12	#89
RHCC or LMC-VE	509.04	#12	#89
Bridge Railings	706.02	#8 or #9	#57/#67 or #7/#78
Patching Structure	710.02	#11	#8
Box Structures	714.02	#91	**See note below
Underdrains	718.02	#8 or #9	#57/#67 or #7/#78
Bridge Deck Overlays	722.03	#11	#8
Three-Sided Structures	723.02	#91	**See note below
MSE Walls	731.05	#8 or #91	#57/#67
MCBR Wall	732.05	#91	**See note below
MCBR Wall	732.05	#8	#57/#67
Wire-Faced MSE Wall	735.05	#8 or #91	#57/#67

** AASHTO M 43 offers nine gradations that meet INDOT # 91 criteria of 100% passing at the 1-in. sieve (AASHTO M 43 #: 5, 56, 57, 6 ,67, 68, 7, 78, 8, 89, 9, 10)

3. COMPARISON OF INDOT AND AASHTO FINE AGGREGATE GRADATIONS

There are five different AASHTO specifications for fine aggregate gradations used in concrete and HMA applications (Table 3.1). In Section 904.04 of INDOT standard specifications, a total of six fine aggregate gradations are detailed. These gradations are intended for various road and bridge construction purposes and share some similarities with the AASHTO gradations listed in Table 3.1. Only one of the INDOT gradations in 904.04, INDOT S&I, shows no similarities with any AASHTO gradations. However, the INDOT S&I fine aggregate is specified for use as a pavement cover to improve friction and reduce slippage caused by ice and snow and, therefore, does not affect concrete or HMA applications.

3.1 INDOT #23 and #24 Fine Aggregate Gradation

INDOT #23 is the primary fine aggregate gradation commonly used for mortar, concrete, and HMA applications. It is also widely utilized across various other construction applications listed in different sections of the INDOT specifications. While INDOT #24 has more specific uses, such as concrete restoration, joint repair, and HMA cover and sealing, it has a similar overall average gradation curve but is slightly finer than INDOT #23 (Figure 3.1). These differences result from INDOT #24 having a higher percentage passing the finer sieves (No. 50 through No. 200) and a lower percentage passing the coarser sieves (No. 4 through No. 30). Additionally, INDOT #23 features significantly tighter gradation bands. These observed gradation differences mainly stem from INDOT #23, which is designated for natural sands, whereas INDOT #24 is recommended for manufactured sands. Naturally produced sand will have greater variability in size, quality and composition, hence the need for a tighter gradation band. On the other hand, manufactured sands are produced precisely to desired size, shape, and so on, using good quality aggregate.

When cross-examining INDOT #23 with AASHTO gradations, the specified gradation in AASHTO M 6 closely matches that of INDOT #23 (Figure 3.2a). The minor difference between the two gradations appears only at the three smallest sieves (No. 50 through No. 200), where AASHTO M 6 has a slightly higher percentage passing and tighter bounds. Meanwhile, INDOT #24 nearly exactly matches AASHTO M 29 #1 gradation (Figure 3.2b).

TABLE 3.1
Summary of AASHTO Specifications for Fine Gradations.

AASHTO	Description	Total Gradations
M 6[1]	Fine Aggregate for Hydraulic Cement Concrete	1
M 29[2]	Fine Aggregate for Bituminous Paving Mixtures	5
M 344[3]	Asphalt Seals	2
M 45[4]	Standard Specification for Aggregate for Masonry Mortar	3
M17[5]	Standard Specification for Mineral Filler for Asphalt Mixtures	1

[1] AASHTO, 2013
[2] AASHTO, 2012
[3] AASHTO, 2022b
[4] AASHTO, 2016
[5] AASHTO, 2019

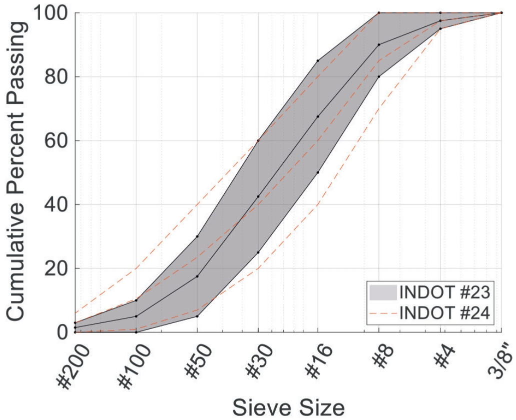
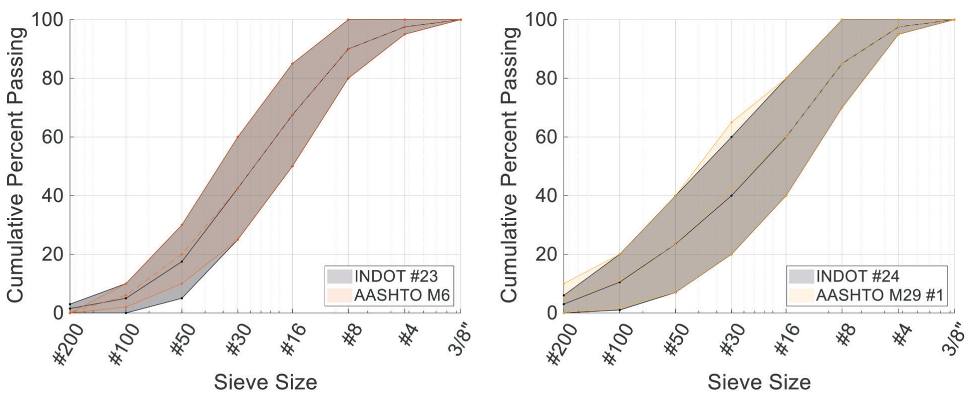


Figure 3.1 Fine Aggregate Gradation Comparison of INDOT #23 and INDOT #24 (INDOT, 2024).

3.2 INDOT #15, #16, and PP Fine Aggregate Gradation

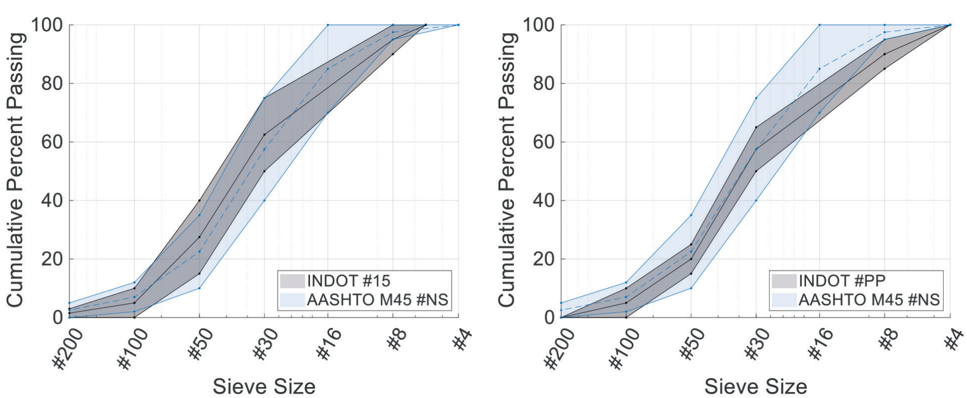
The INDOT #15 fine aggregate gradation is intended for masonry mortar and is specified to be used for pneumatically placed mortar. It closely matches the AASHTO M 45 natural sand (NS) gradation (Figure 3.3a). Although both have similar average gradation curves, INDOT #15 has narrower gradation limits. However, AASHTO M 45 NS offers greater flexibility in its gradation bounds. INDOT PP fine aggregate is designated for use in mortar mixes that are pneumatically placed, as an alternative to INDOT #15. Despite INDOT PP having a similar average gradation curve as INDOT #15, INDOT PP has significantly tighter gradation limits, and more importantly, a lower percent passing at the No. 8 sieve. Therefore, the designated AASHTO fine aggregate gradation for mortar is a slightly worse substitute (in terms of similarity) for INDOT PP due to the passing limit at the No. 8 sieve (Figure 3.3b).

For mineral filler used in SMA, INDOT #16 is specified. It has a similar average gradation curve to the gradation in AASHTO M 17 (Standard Specification for Mineral Filler for Asphalt Mixtures), but INDOT #16 has a finer gradation (Figure 3.4). This difference is due to variations in the sieves used for the two gradations. Both gradations use three sieves in total; but they share only one common sieve at the smallest size (No. 200). The other two sieve sizes for INDOT #16 are No. 30 and No. 100, whereas AASHTO M17 employs larger sieves, No. 16 and No. 50. As a result, AASHTO M 17 has a slightly coarser gradation.



(a) (b)

Figure 3.2 Fine Aggregate Gradation Comparison of (a) INDOT #23 (INDOT, 2024) With AASHTO M 6 (AASHTO, 2013) and (b) INDOT #24 (INDOT, 2024) With AASHTO M 29 #1 (AASHTO, 2012).



(a) (b)

Figure 3.3 (a) INDOT #15 Comparison With AASHTO M 45-NS and (b) INDOT PP Comparison With AASHTO M 45-NS (AASHTO, 2019).

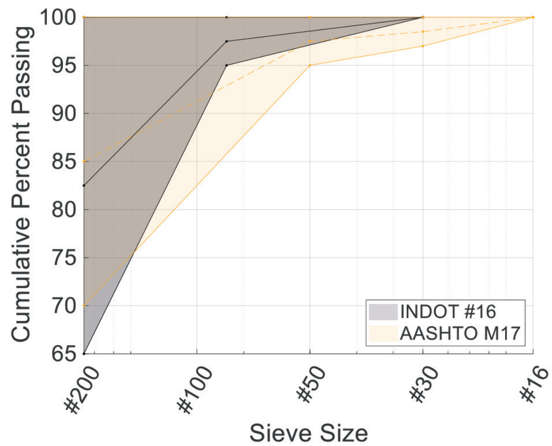


Figure 3.4 INDOT #16 Comparison With AASHTO M 17 (AASHTO, 2019; INDOT, 2024).

4. NEIGHBORING STATES CROSS-ANALYSIS WITH INDOT AND AASHTO

This study assessed the department of transportation (DOT)-specified gradations of four states neighboring Indiana: (i) Illinois, (ii) Michigan, (iii) Kentucky, and (iv) Ohio. The evaluation involved a cross-analysis with INDOT and AASHTO gradations for both coarse and fine aggregates.

4.1 Review of Coarse Aggregate Gradations

Table 4.1 summarizes findings for coarse aggregate gradations from INDOT, AASHTO, ASTM, and neighboring state DOTs. Illinois and Michigan have gradations similar to Indiana; however, they list 24 and 25 gradations, respectively, which are significantly more than the 12 gradations from Indiana. This could pose challenges for Illinois and Michigan if they adopt

TABLE 4.1
Coarse Aggregate Comparison of AASHTO With IN, IL MI, KY, OH, and ASTM.

AASHTO		Indiana[1]	Illinois[2]	Michigan[3]	Kentucky[4]	Ohio[5]	ASTM C33[6]	ASTM D448[7]
	1				1	1	1	1
	2		1		2	2	2	2
	24				23	24		24
	3	2	3	9	3	3	3	3
	357		37, 311		357	357	357	357
	4				4	4	4	4
	467		57, 511		467	467	467	467
	5				5	5	5	5
	56					56	56	56
AASHTO M 43[8]	57	5	7	6AAA	57	57	57	57
	6					6	6	6
	67	8	11	17A	67	67	67	67
	68				68	68		68
	7					7	7	7
	78				78	78		78
	8	11/11SC	20	29A	8	8	8	8
	89	16SC	16	34R, 34G		89	89	89
	9					9	9	9
	10				10	10		10
	A			Class I		A	A	
	B	53	4			B	B	
AASHTO M 147[9]	C	73	10	23A, 23AA	Dense	C	C	
	D					D	D	
	E					E	E	
	F					F	F	

[1] INDOT, 2024
[2] IDOT, 2022
[3] MDOT, 2020
[4] KYTC, 2019
[5] ODOT, 2023
[6] ASTM, 2023
[7] ASTM, 2022
[8] AASHTO, 2005
[9] AASHTO, 2017

TABLE 4.2
Fine Aggregate Comparison of AASHTO With IN, IL, MI, KY, and OH.

AASHTO		Indiana[1]	Illinois[2]	Michigan[3]	Kentucky[4]	Ohio[5]
Concrete	M 6	23	2		Concrete	M 6
Asphalt	M 29-1	24	3	2NS, 2SS		M 29-1
Asphalt	M 29-2					M 29-2
Asphalt	M 29-3		7			M 29-3
Asphalt	M 29-4					M 29-4
Asphalt	M 29-5		1			M 29-5
Masonry Mortar	M 45-NS	15		2MS	Mortar	M 45-NS
Masonry Mortar	M 45-MS					M 45-MS
Asphalt Sand Seals	M 344-I					M 344-I
Asphalt Sand Seals	M 344-III		24	2FA	Micro-surface - II	M 344-III
Asphalt Sand Seals	M 344-III		23	3FA	Micro-surface - III	M 344-III
Mineral Filler	M17	16	Filler	3MF	Filler	M17

[1] INDOT, 2024
[2] IDOT, 2022
[3] MDOT, 2020
[4] KYTC, 2019
[5] ODOT, 2023

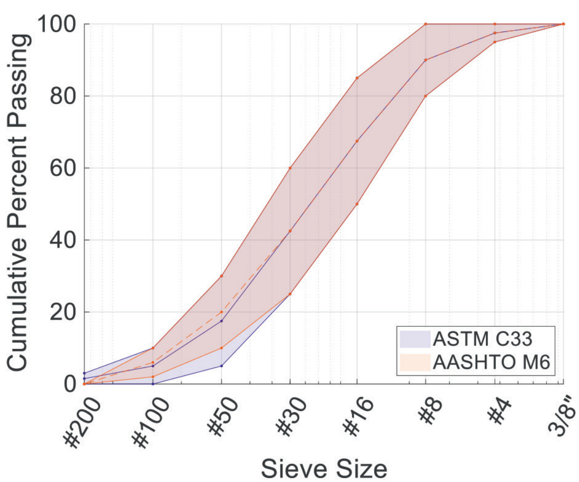


Figure 4.1 Fine Aggregate Gradation Comparison of AASHTO M 6 (AASHTO, 2013) and ASTM C33 (ASTM, 2023).

AASHTO gradations, given their low similarity to AASHTO. Ohio does not have its own gradations but specifies AASHTO gradations. Kentucky lists 24 gradations, most of which are identical to AASHTO M 43, indicating fewer issues if they adopt AASHTO gradations. Additionally, ASTM D448 is identical to AASHTO M 43, both intended for road, bridge, and construction applications, with the same gradations. ASTM C33, designed specifically for concrete applications, uses most of the same gradations as AASHTO M 43, except for #24, #68, #78, and #10. It also includes an additional No. 200 sieve with a 0–1% passing threshold for all the listed gradations.

4.2 Review of Fine Aggregate Gradations

Table 4.2 summarizes fine aggregate grading standards from INDOT, AASHTO, ASTM, and neighboring state DOTs. Ohio relies on AASHTO gradations without listing unique gradations. Michigan, Kentucky, and Illinois include additional gradations specifically for asphalt sand seals, aligning with the AASHTO M 344 (Materials for Sand Seals), whereas Indiana does not. Aside from this, all states specify fine aggregate gradation ranges for use in concrete, mortar, HMA, and mineral filler. Notably, Illinois has a significantly larger variety of fine aggregate gradations, each tailored to different applications.

Furthermore, ASTM C33 specifies fine aggregate gradations for concrete that slightly differ from those in AASHTO M 6 (Figure 4.1). Specifically, AASHTO M 6 has tighter gradation limits at the smallest three sieves, ranging from No. 50 to No. 200.

5. SURVEY AND INTERVIEW RESULTS

To gather more information on the current consensus regarding existing practices for aggregate gradations, three surveys were developed. Each survey targeted specific audiences: (i) aggregate producers; (ii) concrete industry stakeholders (contractors, producers, and engineers/designers); and (iii) HMA industry stakeholders (contractors, producers, and engineers/designers). Responses from these surveys offered insights into current industry practices related to aggregate gradation according to INDOT, AASHTO, and other organizations. Topics covered included challenges faced, economic and design considerations, preferences for gradations to produce or use, and other relevant factors. The feedback collected will help determine whether INDOT should adopt AASHTO gradations. Participant responses were recorded anonymously. Additionally, the surveys were distributed to engineers responsible for concrete and HMA mixture design, including personnel from both INDOT and private consulting firms.

5.1 Survey Results

5.1.1 Aggregate Producers Survey Results

A total of 32 participants responded to the aggregate producer survey. Each was affiliated with an aggregate producer operating in Indiana, though some producers also operate in neighboring states such as Illinois, Ohio, Kentucky, Michigan, and others. The survey gathered insights on the benefits and challenges of producing INDOT versus AASHTO gradations, along with feedback on additional relevant considerations for the study. Most responses primarily focused on coarse aggregate gradations.

When assessing the responses regarding switching gradations, 20 out of the 23 respondents reported having general difficulties with having to switch between INDOT and AASHTO/ASTM/other agency gradations (Figure 5.1). The challenges were due to issues such as frequent plant adjustments of sieves and crushers, material waste, quality control, and storage capacity to maintain stockpiles from the multiple gradation entities.

Aggregate producers must often switch between INDOT and AASHTO, due to some producers serving multiple states. In which all neighboring states use different gradations than INDOT, and some even having identical gradations to AASHTO. Other instances of switching between INDOT and AASHTO come from clients performing commercial work. Additionally, producers often have clients that require ASTM gradations, which are nearly identical to AASHTO gradations.

It was also reported by 16 of 25 participants that the production tolerances differ between INDOT and AASHTO, contributing to the difficulties in the quality control of gradations faced when switching between INDOT and AASHTO. By adopting AASHTO gradations, INDOT can streamline the aggregate gradation specifications, reducing the mentioned difficulties from switching between INDOT and AASHTO gradations. A majority of survey participants found AASHTO gradations to be favorable for aggregate producers who have customers in multiple states (Figure 5.2).

Regarding gradation preferences, 19 of the 29 respondents reported that AASHTO/ASTM gradations are easier to produce, and 16 of the 29 participants found them to be more economical to produce. Overall, 62% of respondents indicated that AASHTO/ASTM gradations are more practical to produce. A majority of aggregate producers favored AASHTO based on positive manufacturing and economic factors (Figure 5.3). As noted, some producers operate in multiple states and prefer using AASHTO because many states have similar gradations. This enhances plant efficiency and provides economic benefits to these producers. Additional support for AASHTO was also linked to manufacturing technical considerations. Producers mentioned that INDOT sometimes has gradations with sieves that conflict with each other, whereas AASHTO gradations tend to have fewer such issues. Producers also reported that AASHTO gradations are easier to modify to meet targets.

It was reported frequently by producers that INDOT gradations have many complications and difficulties regarding the control of fines, hence their preference for AASHTO gradations. This is because INDOT gradations have more fines, causing slower production rates, while AASHTO gradations have fewer fines. Producers mentioned finer particles in a product are much more difficult to control with plant adjustments. Producers also reported instances that customers prefer AASHTO gradations since they have fewer fines. It was reported that INDOT #8 specifically is affected by this issue requiring additional time and resources. Due to INDOT #8 being a widely used gradation, this leads to a preference for AASHTO gradations. Concerns regarding INDOT having stringent requirements for controlling fines and decant were expressed.

Most participants, from the perspective of the producers, responded positively to the idea of INDOT adopting AASHTO gradations (Figure 5.4). Moreover, only two out of

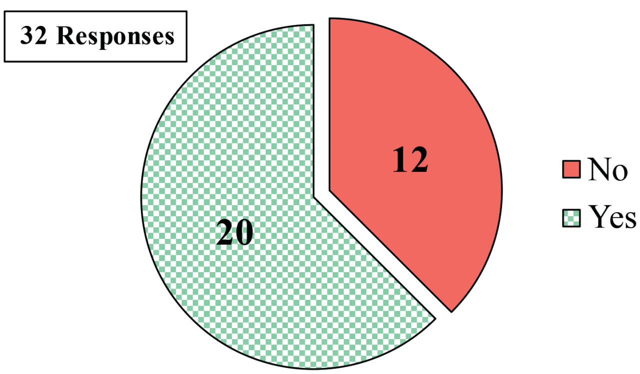


Figure 5.1 Aggregate Producer Survey Results for Question 1: "Are there any general difficulties with having to switch between INDOT and AASHTO/ASTM/Other agency gradations?"

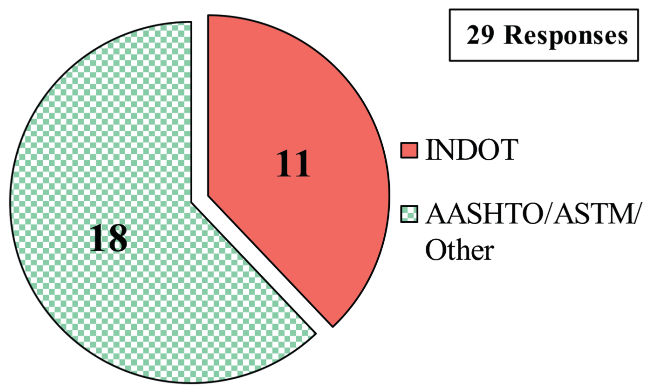


Figure 5.3 Aggregate Producer Survey Results for Question 2.3: "From a manufacturing perspective, which gradation is more practical to produce?"

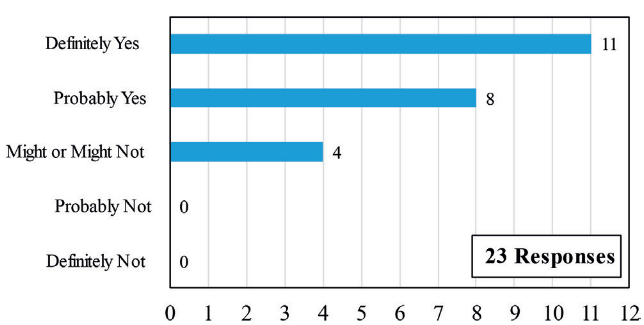


Figure 5.2 Aggregate Producer Survey Results for Question 9.2: "Are AASHTO gradations more favorable for aggregate producers that operate in multiple states?"

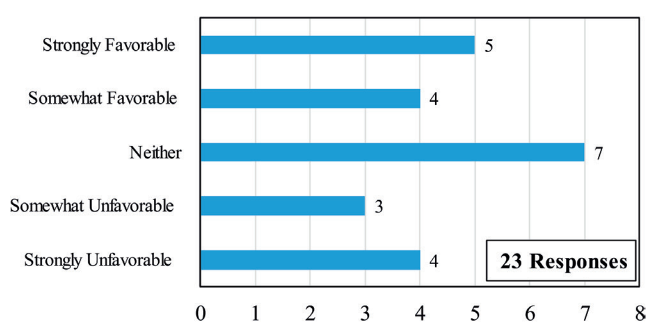


Figure 5.4 Aggregate Producer Survey Results for Question 9: "Overall, from a producer's perspective, what would the reaction be if INDOT adopted AASHTO gradations?"

21 participants believed it is not feasible to adopt AASHTO gradations. Additionally, all 21 participants agreed that it is more practical for producers operating in multiple states to use AASHTO instead of INDOT gradations. Only one participant thought that AASHTO gradations would not meet all of INDOT needs. Overall, the survey responses showed a strong preference for INDOT to adopt AASHTO gradations. Also, 32% of the 22 participants believed that a 2-year transition period is ideal, while 32% thought 5 years was a more reasonable time frame.

5.1.2 Concrete Industry Stakeholders Survey Results

Eight participants completed the survey, including four concrete producers and four respondents who identified as both producers and contractors. When asked to compare INDOT gradations with AASHTO/ASTM gradations, half of the respondents believed AASHTO/ASTM gradations were better. The remaining respondents believed there were no differences, and more importantly, no one considered AASHTO gradations to be worse than INDOT gradations (Figure 5.5). Reported potential benefits of adopting AASHTO gradations included consistency across multiple agencies and states. Furthermore, participants highlighted the opportunity to simplify communication about projects across different states. Additionally, respondents mentioned that increased flexibility for concrete producers and contractors would be possible, as AASHTO has wider gradation ranges, more options, and greater versatility for various projects (e.g., State, Federal, Commercial). Respondents noted that switching would not significantly disrupt concrete mixtures due to blending, primarily because of mixture optimization using the tarantula curve for concrete pavement design, which makes blending more critical than initial gradation. Reported drawbacks were few and mainly related to setbacks facing aggregate producers rather than concrete producers and contractors. These concerns included resistance from aggregate producers to change and the potential for reduced product quality due to wider gradation bounds from AASHTO. Notably, five out of eight respondents said they usually do not request a specific gradation (INDOT or AASHTO); instead, aggregate producers supply what is available.

Regarding agency preference for aggregate gradations, only one participant preferred INDOT gradations. While six of the eight respondents favored AASHTO or ASTM gradations (AASHTO and ASTM have similar, interchangeable gradations), the majority of participants preferred AASHTO gradations (Figure 5.6). Respondents cited that AASHTO gradations offer flexibility, standardization, and broader applicability across states as primary reasons for their preference. An additional reason was that the primary coarse aggregate for INDOT gradation used in concrete (#8) is too fine and lacks sufficient 3/4-in. material, which causes segregation and results in poor-quality concrete or the need for extra blending, leading to higher costs. Respondents also noted that AASHTO/ASTM gradations offered greater flexibility for customers and that the Federal Aviation Administration (FAA) and commercial specifications aligned with AASHTO gradations, highlighting their multi-agency compatibility.

Most participants (five out of eight) indicated that the current gradations listed in the INDOT specifications (904.03[e]) have limitations. They noted significant differences in gradation between INDOT and neighboring states. Some participants expressed a desire to modify existing INDOT gradations (e.g., coarser #8), but they are not always able to get these requests approved. Challenges with INDOT gradations also include the difficulty of controlling and maintaining fines (No. 200 sieve or smaller), which affects product consistency. This variability in fines makes it hard for CAPP producers to meet INDOT limit requirements. Using AASHTO gradations would help, as they allow wider limits on the No. 200 sieve, reducing the risk of exceeding specification limits during production.

Overall, six of the eight respondents indicated that they would benefit from switching to AASHTO gradations (Figure 5.7). This would provide concrete producers and contractors with more variety in aggregate gradation options, offering greater flexibility in designing concrete mixtures. Respondents also mentioned that this change would bring simplicity and consistency, especially for both in-state and out-of-state customers. A key benefit highlighted by respondents was that INDOT's structural concrete currently contains excess cement paste, and

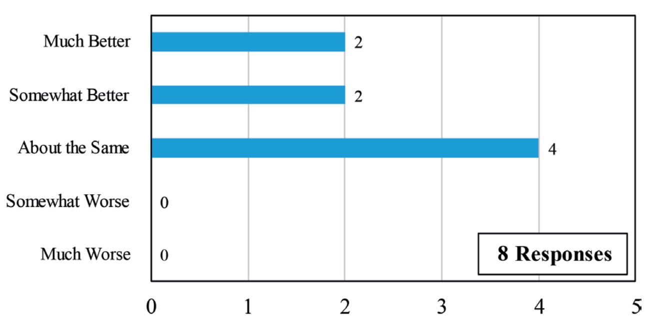


Figure 5.5 Concrete Industry Stakeholders Survey Results for Question 1: "DOTs in states like Ohio and Kentucky use AASHTO or ASTM gradations, while Michigan and Illinois follow their own state-specific standards. Other specifiers, such as the FAA or commercial clients, may also require unique gradations. In your opinion, how do these alternative gradations compare to INDOT's standard gradations for concrete production or base/backfill applications?"

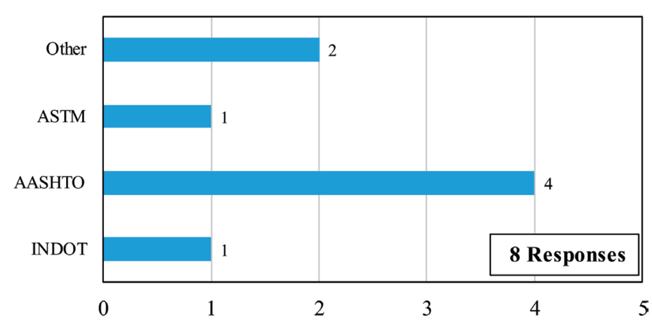


Figure 5.6 Concrete Industry Stakeholders Survey Results for Question 2: "Do you have a preference between using INDOT gradations and those specified by other agencies (e.g., AASHTO, ASTM, FAA, or state/commercial specifications)?"

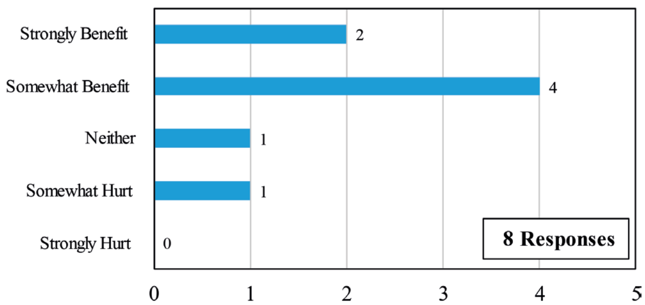


Figure 5.7 Concrete Industry Stakeholders Survey Results for Question 6: "Overall, would you benefit from or be hurt by a change from INDOT's standard gradations to AASHTO or ASTM gradations?"

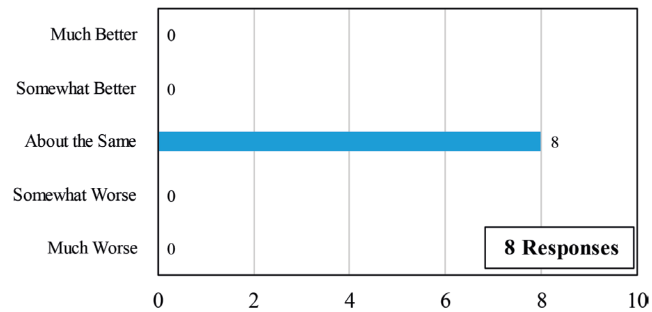


Figure 5.8 HMA Industry Stakeholders Survey Results for Question 1: "DOTs in states like Ohio and Kentucky use AASHTO or ASTM gradations, while Michigan and Illinois follow their own state-specific standards. Other specifiers, such as the FAA or commercial clients, may also require unique gradations. In your opinion, how do these alternative gradations compare to INDOT's standard gradations for concrete production or base/backfill applications?"

adopting AASHTO gradations could improve mixture optimization of structural concrete by reducing cement paste content due to the coarser gradation structure resulting from using AASHTO sizes. This is particularly relevant as INDOT moves toward performance-based mixture specifications for structural concrete. By replacing the primary coarse aggregate gradation, that is, the relatively fine INDOT #8, with a coarser AASHTO alternative, concrete production costs could decrease through less blending, improved uniformity, and fewer aggregate bins needed. Additionally, adopting AASHTO gradations would likely be less challenging, as some concrete contractors and producers already use these gradations due to their experience serving customers in neighboring states. Respondents generally believe that such a transition would take approximately one year.

5.1.3 HMA Industry Stakeholders Survey Results

The third survey was designed for HMA producers and contractors, with a total of eight participants' responses recorded. All participants identified themselves as affiliates of companies that are HMA laydown contractors and producer contractors.

Based on the results, all participants agreed that AASHTO, ASTM, and other agency gradations compare similarly to INDOT gradations for HMA applications (Figure 5.8). When asked about potential benefits if INDOT adopted AASHTO gradations, seven out of eight respondents said this would simplify procedures between Indiana and neighboring states. Several also pointed out that contractors working across state lines or for multiple agencies (e.g., FAA, commercial projects) were already more familiar with AASHTO gradations, so the switch would reduce confusion and help standardize operations. One additional benefit mentioned was that AASHTO required a finer gradation below the maximum sieve size than INDOT. This would lead to less material being retained on the same sieve during blending of the final combined gradation, thereby positively impacting the VMA. Respondents also noted that AASHTO gradations are comparable with INDOT (e.g., INDOT #8 and AASHTO #67), which offer better control of coarseness while maintaining sufficient finer material, which benefits VMA.

Although participants expressed more incentives if INDOT adopted AASHTO gradations, five out of eight participants commented on similar potential drawbacks. They believe that the initial adjustment period will cause confusion and difficulties. Some respondents noted that adopting AASHTO gradations might lead to mixture redesigns if new gradations differ significantly (e.g., INDOT #12 and AASHTO #89). A specific concern mentioned was the need to revise the blending and grading requirements for HMA and how much it would be affected. Participants were asked whether INDOT or AASHTO/ASTM required more blending efforts to meet a specified final gradation, and seven out of eight participants do not think there is any difference. However, one participant was unsure, noting it will not be clear until after the switch. Instead, the same participant suggested that whether INDOT or AASHTO/ASTM requires more blending would depend on the individual aggregate producer. Minor concerns during the initial transition period include the potential for increased variability and supply limitations, which could lead to more waste and higher costs in HMA production.

All participants reported that they do not request a specific gradation, such as INDOT or AASHTO, and instead rely on aggregate producers to provide what is available, with HMA producers and contractors adapting accordingly (Figure 5.9). Participants were divided on their preferred agency for gradations, with some favoring AASHTO/ASTM, others favoring INDOT, and some having no preference. Additionally, five out of eight participants noted that AASHTO/ASTM offers a uniform standard that simplifies HMA production, as ASTM is used in commercial, FAA, and U.S. Army Corps of Engineers (USACE) projects and closely resembles AASHTO. As previously mentioned, some serve neighboring states where AASHTO gradations are more similar than those of INDOT. However, one of the two participants who preferred INDOT values the convenience of the accumulated data from using INDOT gradations. The other participant who favored INDOT mentioned that its gradations are sufficiently effective, and they would prefer stricter production tolerances. This respondent explained that aggregate variability, rather than gradation, is responsible for the current inconsistency in HMA mixes due to wider production targets by aggregate suppliers.

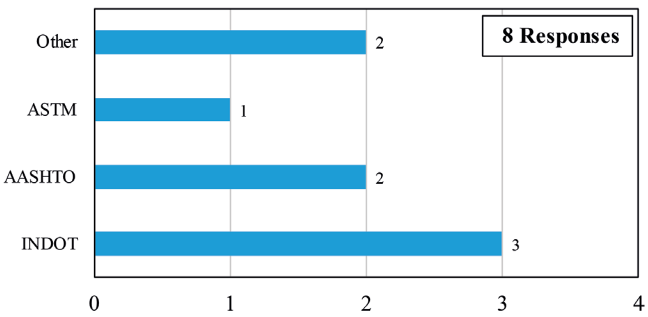


Figure 5.9 HMA Industry Stakeholders Survey Results for Question 2: "Do you have a preference between using INDOT gradations and those specified by other agencies (e.g., AASHTO, ASTM, FAA, or state/commercial specifications)?"

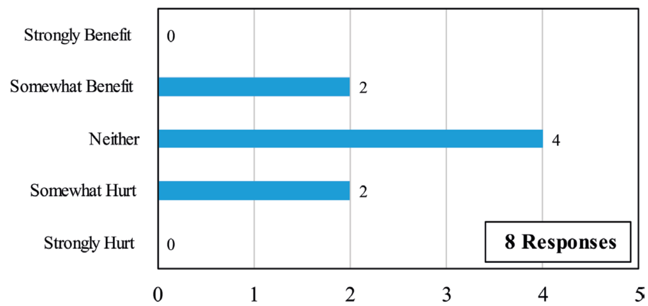


Figure 5.10 HMA Industry Stakeholders Survey Results for Question 6: "Overall, would you benefit from or be hurt by a change from INDOT's standard gradations to AASHTO or ASTM gradations?"

Based on the survey results for HMA affiliates, four out of eight responders are indifferent to INDOT switching to AASHTO gradations since they follow the QA specifications provided by CAPP (Figure 5.10). Because aggregates used in HMA mixtures require additional blending from the initial gradations anyway, this change might not significantly impact them. Additionally, three participants are slightly skeptical due to the uncertainty about how the switch could affect blending, supply, waste produced, and production. Furthermore, five out of eight participants do not believe that INDOT's current standard gradations have any gaps or limitations. Of the three respondents who identified limitations, concerns include reliance on QA finer products to achieve adequate mixtures. The need for specified gradations that can reduce dependence on QA products would enable aggregate producers to deliver more consistent products for HMA producers, thus reducing the necessity for end-user blending. AASHTO might be able to meet this need. However, it was often noted that switching to AASHTO would create uniformity in specifications, which would benefit HMA affiliates that operate across multiple states and/or work on FAA and commercial projects. On average, the participants believe that a transition period of about two years would be ideal if INDOT were to adopt AASHTO gradations.

5.2 Interview Results

5.2.1 Aggregate Producers Interview Results

Aggregate producers interviewed operated either a gravel pit or a crushed stone plant. Those that operated a gravel pit produce only natural fine aggregate or gravel. While the latter produces coarse aggregate from crushing limestone and/or dolomite, these plants can also produce manufactured fine aggregate. However, producing manufactured fine aggregate is uncommon due to its complex process. Additionally, natural aggregate (INDOT #23 or AASHTO M 6) is used significantly more than manufactured fine aggregate. Since most aggregate producers operate stone-based plants, they had little-to-no concerns regarding fine aggregate gradations, and the survey and interview questions focused mainly on coarse aggregates. Furthermore, there are significantly more coarse aggregate products.

Aggregate producers expressed a preference for the tighter control of the fines in coarse aggregate in AASHTO gradations. For example, the widely used coarse aggregate for concrete, AASHTO M 43 #57 and #67, has tighter bounds than the equivalent INDOT #8 at the No. 4 and No. 8 sieves. This clarifies the previously expressed concerns from the surveys regarding INDOT gradations being more challenging to control the finer portion of coarse aggregates (Section 5.1.1). The tighter bounds may also lead to operational adjustments if AASHTO gradations are adopted. Concerns about difficulties controlling fines (passing No. 200 sieve) when producing INDOT gradations were addressed by aggregate producers. This is because INDOT gradations have stricter overall bands and a limit on fines (passing No. 200 sieve). For INDOT gradations, fines are called decant. Most INDOT gradations specify maintaining a decant limit up to 3% (depending on the application). Excess fines are removed through decanting (washing with water), which is highly sensitive to fines. Since AASHTO gradations have more flexible bounds and are based on performance, changes in fines have less impact on the gradation, especially since there is no explicit requirement for decant content. This makes AASHTO gradations better aligned with plant operations, reducing quality control (QC) burdens and fines sensitivity.

Regarding the impact on production efficiency, most producers believe that the long-term disruption will be minimal, but there will be short-term effects from plant adjustments and DOT-sanctioned product testing. Various scenarios were considered regarding the impact on product QC by aggregate producers if AASHTO gradations were adopted. Concerns about negative effects on product quality were raised due to the need to rebuild data histories and recalibrate plant operations. A neutral view was also expressed regarding the impact on product quality, given the tighter bounds of AASHTO gradations for customers. For aggregate producers operating in multiple states, improvements in product quality are expected from a uniform gradation specification, due to reduced stockpiles and fewer plant adjustments to accommodate different gradations.

If AASHTO gradations are adopted, some short-term financial impact is expected initially. This would lead producers to adjust the entire plant's gradation bands, as indicated by the tighter limits for finer sieves and broader limits for coarser sieves seen in the most commonly used AASHTO gradations. Additionally, producers who handle more complex gradations may face financial impacts due to necessary equipment modifications such as screens, gates, and chutes. These modifications often require significant capital investment for purchase and installation. However, producers expect minimal long-term financial effects. They also noted that adopting AASHTO gradations would not increase the number of marketable products, as plants operate at maximum capacity and this would remain unchanged. Furthermore, those serving multiple customers see potential for cost savings through a standardized gradation specification.

Ultimately, support for adopting AASHTO gradations will vary depending on the aggregate plant. Operators in Kentucky, Ohio, and Indiana will be more likely to favor the switch because AASHTO gradations are used by ODOT and KYTC. Additionally, producers serving customers in FAA, USACE, and commercial projects will be more inclined to adopt AASHTO gradations since these projects use AASHTO or ASTM standards. These scenarios offer financial advantages for aggregate producers through streamlined operations. However, producers in Illinois and Michigan will be less inclined to switch because their DOT gradations align more closely with existing INDOT gradations. This may lead to negative implications, such as the continued need for dual stockpiles. Producers who only serve Indiana customers are less likely to switch, as they would benefit more from maintaining current operations and would have to restructure plants and rebuild data histories. Lastly, producers of only natural fine aggregate will remain largely unaffected, since Indiana's (INDOT #23) and neighboring states' natural fine aggregate gradation is essentially similar to the AASHTO M 6 equivalent.

Aggregate producers highlighted the importance of customer acceptance, as it is crucial for adopting AASHTO standards. They oppose grandfathering current INDOT gradations to avoid confusion, such as between INDOT #8 and AASHTO M 43 #67. Producers expect INDOT to offer technical education and support to industry members and to reassess concrete and HMA mixture designs if AASHTO gradations are implemented. For a smooth transition, they recommend that INDOT facilitate collaboration among aggregate producers, HMA and concrete producers, and engineers.

5.2.2 Concrete Industry Stakeholders Interview Results

Concrete industry stakeholders, such as contractors, producers, and engineers/designers, were interviewed and generally expect positive effects, with only minor negative impacts on concrete mixture designs and production. They believe that most negative impacts would target aggregate producers, while ready-mix concrete (RMC) producers might face fewer issues, and engineers/designers would experience mostly advantages. However, stakeholders do not anticipate strong resistance from concrete engineers, designers, or contractors. Instead, they foresee more resistance from aggregate producers due to impacts on plant production systems. This preference for AASHTO/ASTM gradations is based on the fact that most engineers and designers are trained using AASHTO/ASTM standards. Additionally, many work for multiple entities such as other state DOTs, FAA, USACE, and commercial projects. Adopting AASHTO gradations could streamline operations because these entities already use or prefer AASHTO/ASTM gradations. This change would eliminate mid-project gradation switches, decrease efforts in trial batching, improve project schedules and timelines, and reduce disruptions in product quality control. Furthermore, one stakeholder noted that AASHTO gradations offer an advantage since they are continually improved and routinely updated through national collaboration.

Adopting AASHTO gradations could enhance concrete mixture optimization by offering greater flexibility in adjusting aggregate gradation and proportions to meet desired properties of both fresh and hardened concrete. Stakeholders mentioned that AASHTO gradations align better with the Tarantula Curve for mixture optimization, because current INDOT gradations cannot reach the 1/2-in. sieve peak. In contrast, AASHTO gradations enable this adjustment on the coarse side, mainly by increasing the proportion of 1/4-in. material. Similar to aggregate producers, concrete stakeholders favor AASHTO gradations because they provide better control over fines (see Section 5.21), which can help reduce the risk of producing lower-quality concrete due to excessive fines.

Overall, concerns about workability and pumpability are minimal, provided that the optimization criteria are met. One stakeholder mentioned that AASHTO gradations might allow more 3/8-in. material and less 1-in. material, which could potentially improve workability further. Concrete stakeholders agreed that additional testing might still be necessary to confirm that workability and pumpability meet requirements under the AASHTO gradation system, especially during the transition period if it is adopted. They also emphasized that companies would need to reassess their internal concrete mixture designs when adopting AASHTO gradations to ensure that optimized mixes continue to meet performance standards. Despite these adjustments, stakeholders do not expect any changes to the concrete class mixtures specified by INDOT.

Lower costs for concrete producers are expected due to reduced stockpiling and improved efficiency at the aggregate plant level. Additional savings may come from decreased QC labor requirements if a standard gradation specification is adopted. Further savings are also possible, since stakeholders noted that AASHTO gradations provide flexibility for different gradations within broader bounds, potentially reducing the need for frequent blending of aggregate stockpiles. However, one stakeholder cautioned that if producers shift toward coarser gradations within the wider AASHTO limits, it could increase blending and costs. Despite this concern, such a scenario seems unlikely because aggregate producers typically customize their products to meet the performance needs and preferences of their customers (concrete stakeholders).

Concrete stakeholders anticipate clear guidance and revised specifications from INDOT if AASHTO gradations are adopted, including critical sieve requirements. They also emphasize the need for INDOT to provide training and educational outreach to concrete producers, contractors, and engineers/designers. Additionally, stakeholders request increased inspection emphasis at aggregate plants under an AASHTO gradation system. Notably, if AASHTO gradations demonstrate concrete mix performance on the Tarantula Curve that is equal to or better than the current INDOT #8 and #11 aggregate, they are more likely to be considered for adoption. Overall, interviews reveal positive outlooks from industry stakeholders, though some practical concerns about impacts on mixture designs, performance, production, and costs were mentioned; most remain supportive overall.

5.2.3 HMA Industry Stakeholders Interview Results

HMA industry stakeholders (producers, contractors, and engineers/designers) foresee little to no impact on HMA mixture designs if AASHTO gradations are adopted. This is because they can produce QA gradations through the INDOT CAPP. This QA system currently allows producers to adjust gradations (within a limit) to meet mixture design requirements. Minimal resistance is expected from HMA stakeholders if AASHTO gradations are adopted, as no changes are anticipated in HMA construction practices. However, similar to concrete stakeholders, it is believed that aggregate producers may resist the switch, since this would require adjustments in production at aggregate plants. Some HMA affiliates indicated that resistance could be more likely from larger HMA companies due to the volume of mixture designs that will need reevaluation (such as mixes currently using INDOT #12). Additional resistance might also come from engineers and designers, since adopting AASHTO gradations may involve a learning curve and familiarity with new specifications.

Adopting AASHTO gradations offers more consistency in aggregate gradations across states and improves compatibility with FAA, USACE, and commercial projects, which often reference AASHTO or ASTM gradations. This change is especially useful for HMA stakeholders operating in multiple states, such as Kentucky and Ohio, where their DOT-specified gradations already align closely with AASHTO standards. Emphasized advantages include a standardized naming system and uniformity in nationwide operations. In HMA mixtures, the wider ranges of AASHTO gradations provide increased flexibility in gradation limits, potentially reducing the need for blending. This can enhance quality control of HMA mixes and may lower production costs. Although gradation optimization is likely to improve with AASHTO adoption, overall HMA costs should stay mostly steady since asphalt binder remains the main expense. Most stakeholders believe no long-term cost increases are expected; however, short-term costs might occur from mixture design reevaluations, trial batch testing, and personnel training. Stakeholders do not anticipate major changes in HMA mixture production, placement, or compaction due to adopting AASHTO gradations.

HMA stakeholders strongly highlighted that shifting to AASHTO gradations will not negatively impact their operations and practices, provided the existing CAPP QA system remains in place. They stressed that retaining the CAPP is essential for ensuring consistent and high-quality HMA. Stakeholders also clarified that their survey and interview responses rely on this assumption. They suggested that the QA gradations and CAPP requirements would remain unchanged, as AASHTO offers gradations comparable to most INDOT gradations.

Stakeholders believe INDOT should review and, if necessary, redefine the critical/control sieves for AASHTO gradations to ensure consistency in HMA mixture production, performance, and quality control. They also expect INDOT to thoroughly evaluate existing specified HMA mixture designs and practices if a transition becomes necessary. However, based on input from an INDOT engineer, the INDOT specifications in Section 400 are expected to remain unchanged, aside from possibly requiring an editorial update. Additionally, stakeholders highlighted the importance of INDOT providing technical support, educational outreach, and industry collaboration to facilitate a smooth and effective transition.

The importance of grandfathering specific existing INDOT gradations was emphasized, especially those crucial to particular HMA mixtures and lacking direct AASHTO equivalents. Examples include INDOT #12 for meeting VMA requirements and INDOT #9 for producing suitable SMA mixtures. However, grandfathering is not necessary and could cause confusion and lead to inconsistent supply from aggregate producers. For INDOT #12, using AASHTO #89 instead could still deliver similar and sufficient VMA performance. Although AASHTO #89 contains less material at the No. 4 sieve, this can be addressed by increasing the proportion of AASHTO #89 in the combined aggregate blend. Stakeholders explained that SMA performance in Indiana is mostly influenced by aggregate strength rather than gradation, making improvements in aggregate shape requirements during production more impactful. Additionally, gradations like INDOT #9 can be effectively produced through blending and mixture optimization while utilizing AASHTO gradations. This approach would ensure HMA stakeholders that the valuable features of some existing INDOT gradations are preserved under an AASHTO gradation system.

Overall, interviews with HMA industry stakeholders indicate that adopting AASHTO gradations would have minimal impact on HMA mixture designs, performance, production, costs, and quality control. This is primarily attributed to the flexibility offered by INDOT's CAPP QA system, which already enables producers to develop gradations that meet desired HMA mixture performance standards. Stakeholders consistently indicated that adopting AASHTO gradations would not result in long-term negative financial effects and is both operationally feasible and practical for HMA producers and contractors. The anticipated disruptions are minor and mostly involve adjustments to mixture design and educational training.

6. SUMMARY OF FINDINGS

6.1 Conclusions

Adopting AASHTO gradations generally provides economic benefits by enhancing aggregate production efficiency. Over the long term, this results in cost savings through streamlined production processes and easier stockpile management. Producers operating in multiple states may experience financial gains due to fewer plant modifications when switching between gradations and a decreased need for duplicate stockpiles. However, short-term costs might include plant reconfigurations, adjustments to customer contracts, new quality control procedures, and rebuilding data records. Stakeholders involved in concrete and HMA expect that initial effects will mainly stem from trial batch testing, but they do not anticipate any long-term negative impacts on their operations. These negative impacts are considered minimal based on survey and interview responses and collected information.

Regarding INDOT adopting AASHTO gradations, aggregate producers remain the critical stakeholders since HMA and concrete producers do not manufacture aggregates. Support among aggregate producers varies by location; those near state borders, such as Ohio and Kentucky, tend to be more supportive due to better alignment with AASHTO gradations, whereas Illinois producers are less supportive. Aggregate producers emphasized that customer demand from concrete and HMA stakeholders will be crucial for the acceptance of AASHTO gradations. Generally, HMA stakeholders favor the change, with minimal concern about potential reevaluations of mixture designs. The overall consensus among aggregate producers is that fine aggregate production will stay mostly unaffected, addressing concerns regarding impacts on fine concrete and HMA mixtures. This is supported by the fact that INDOT natural sand gradation (#23) closely matches the natural sand gradation of AASHTO (M 6), Illinois, Ohio, Michigan, and Kentucky.

Most survey participants from the concrete and HMA sectors prefer AASHTO gradations because it ensures consistency and simplifies production across neighboring states and projects such as commercial and FAA. Since AASHTO gradations closely match those in neighboring states and ASTM standards, stakeholders highlighted benefits, including continuous, innovative updates through national collaboration and reduced variability in fines (No. 200 or less), which leads to higher-quality products. Concrete industry stakeholders especially appreciate the additional flexibility AASHTO gradations offer for designing and optimizing concrete mixes. They also mentioned excess cement paste in current INDOT pavement and structural concrete mixes. The generally coarser gradations of AASHTO, which still maintain adequate fineness and provide a broader range of options, offer a practical solution to this problem. This advantage is especially relevant as INDOT moves toward performance-based specifications for structural concrete.

Although HMA industry stakeholders identified many potential benefits with few drawbacks when considering the adoption of AASHTO gradations, some were indifferent. This is mainly because they follow the QA specifications of CAPP and require additional blending of initial gradations. HMA stakeholders emphasized the importance of maintaining and continuing the CAPP QA system, as it is the main reason they do not expect significant changes if AASHTO gradations are adopted. HMA affiliates expressed concerns about the impact on existing HMA mixture designs that specify the use of INDOT #12 or INDOT #9, as both differ significantly from their closest AASHTO equivalents. However, these INDOT gradations can be adequately replaced with AASHTO gradations through proper adjustments in volumetric proportioning or blending.

The results of this study demonstrated that adopting AASHTO gradations offers significant benefits for aggregate, concrete, and HMA production in Indiana. These benefits include, but are not limited to, enhanced infrastructure performance, increased operational efficiency, and long-term economic gains. According to the literature review and survey/interview responses, industry stakeholders in the aggregate, concrete, HMA, and construction sectors expressed strong and consistent support. Additionally, AASHTO provides a more modern and well-developed gradation system, supported by frequent updates at the national level and ongoing technical innovation. In comparison, current INDOT gradations are outdated relative to modern practices for optimizing concrete and HMA mixtures. AASHTO gradations better support emerging performance-based mixture specifications in Indiana and enable more effective mixture optimization.

6.2 Recommendations

It is recommended that INDOT transition from its current aggregate gradation standard, as outlined in the INDOT Standard Specifications (Section 900), to those specified by AASHTO. Specifically, they should adopt AASHTO M 43 and M 147 for coarse aggregates, along with AASHTO M 6, M 17, M 29, and M 45 for fine aggregates. This transition is further supported by the ability to standardize more uniformly with other states, ASTM, FAA, and USACE specifications, since AASHTO gradations are either identical or more closely aligned with those entities. Additionally, this change could enhance efficiency and simplify contracting, leading to economic benefits and opportunities. Although initial challenges may arise from adjustments at aggregate plants and the review of HMA and concrete mix designs, stakeholders have indicated that the long-term advantages outweigh these initial challenges. This recommendation is further supported by the shift toward performance-based specifications by the agency (INDOT) for structural concrete and a focus on reducing cement paste content through improved mixture optimization.

To facilitate the transition to the AASHTO gradation system, it is important to recognize that support from aggregate producers will differ by geographic location. Producers supplying aggregates to Kentucky and Ohio generally demonstrate more support, as their systems align more closely with their respective DOTs. Additionally, stakeholders in the concrete industry noted that AASHTO gradations could provide more flexibility in optimizing concrete mixes. HMA industry stakeholders believe AASHTO offers many advantages and should not be negatively affected but emphasized the importance of maintaining the CAPP QA system for a successful transition. Furthermore, adopting the AASHTO system will require INDOT to review and verify control and critical sieve requirements, as well as reassess existing concrete and HMA mixture design standards. However, the consensus is that transitioning to AASHTO should not cause significant issues.

6.3 Future Work

While the feasibility of adopting AASHTO gradations appears strong and practical based on the findings, further research is necessary to better understand their impact on HMA and concrete mixtures, followed by any needed adjustments.

Increased collaboration with HMA producers could help clarify effects on blending requirements. If AASHTO gradations are adopted, establishing a systematic framework to support their integration is essential. Additionally, INDOT should develop clear guidelines to assist industry professionals. Future research should also investigate why ITM 226 is underutilized in Indiana. Furthermore, a thorough evaluation of how AASHTO gradations perform within performance-based mixture optimization tools, such as the Tarantula Curve, is recommended.

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APPENDICES

Appendix A. List of Acronyms

Appendix B. INDOT Coarse Aggregate Gradation Summary of Application

Appendix C. INDOT Fine Aggregate Gradation Summary of Application

Appendix D. Aggregate Producers Survey Responses

Appendix E. Concrete Industry Stakeholders Survey Responses

Appendix F. HMA Industry Stakeholders Survey Responses

Appendix A. List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ASTM	ASTM International
CAPP	Certified Aggregate Producer Program
CF	Coarseness factor
CPM	Prepackaged Concrete Patching Material
DOT	Department of transportation
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
HMA	Hot-Mix Asphalt
IDOT	Illinois Department of Transportation
INDOT	Indiana Department of Transportation
ITM	Indiana Test Method
KYTC	Kentucky Transportation Cabinet
LMC-VE	Latex-Modified Concrete Very Early Strength
MCBR	Modular Concrete Block Retaining Wall
MDOT	Michigan Department of Transportation
MSE	Mechanically Stabilized Earth
NCHRP	National Cooperative Highway Research Program
NMAS	Nominal Maximum Aggregate Size
NS	Natural Sand
ODOT	Ohio Department of Transportation
OPCC	Ordinary Portland Cement-Based Concrete
PCC	Portland Cement Concrete
PG	Pea Gravel
QA	Quality Assurance
QC	Quality Control
RHCC	Rapid Hardening Cement-Based Concrete
RMC	Ready-Mix Concrete
SC	Seal Coat
SMA	Stone Matrix Asphalt
USACE	U.S. Army Corps of Engineers
VFA	Voids Filled With Asphalt
VMA	Voids in Mineral Aggregates
WF	Workability Factor
WRA	Water-Reducing Admixture

Appendix B. INDOT Coarse Aggregate Gradation Summary of Application

Table B.1

Coarse Aggregate Use for INDOT #’s 2, 5, 8. (Section 904.03).

	INDOT # 2 AASHTO M 43 - # 3		INDOT # 5 AASHTO M 43 - # 57		INDOT # 8 AASHTO M 43 - # 57 or 67	
	Description	**Subsection**	**Description**	**Subsection**	**Description**	**Subsection**
Section 200	Stable Construction Entrances	205.10	Stabilizing Material	203.09	Temporary revetment riprap	205.05
	Geotextile Drainage Blanket (No ACBF)	214.02	Temporary revetment riprap	205.05	Filter Berm	205.06
			Filter Berm	205.06	Subgrade: Type ID, 2B	207.04
			Subgrade: Type ID, 2B	207.04	End bent Backfill: Crushed Stone or ACBF, Class D or higher	211.02
			Structure Backfill: Type 3	211.03 *	Structure Backfill: Type 3	211.03 *
			Geotextile Drainage Blanket (No ACBF)	214.02		
Section 300	Aggregate Base: Class D or higher	301.02	Aggregate Base: Class D or higher	301.02	Aggregate Base: Class D or higher	301.02
					PCCP Subbase Drainage Layer: Class B or higher	302.02
					PCC Base: Class A or higher	305.02
Section 400					Cover Aggregate (7/7P): Class B or higher	404.04
Section 500					PCCP Coarse Aggregate: Class AP	502.02 **
					PCCP Full Depth Patching: Class AP or higher	506.02 **
Section 600					Shoulder drains: Class D <	608.02
					Reinforced Concrete Bridge Approaches: Class B or higher	609.02
					Monuments, Markers, Parking Barriers: Class A or higher	615.02
Section 700					Structural Concrete Exposed: Class A or higher	702.03 **
					Structural Concrete Non-Exposed: Class B or higher	702.03 **
					Bridge Railings: Class B or higher	706.02
					Aggregate Base for Reinforced Concrete Box: Class D or higher	714.05
					Grated Box End Sections aggregate leveling bed	715.02
					Underdrains (6”): Class E or higher	718.02
					Aggregate Base for Footings: Class D or higher	723.09
					MSE Walls: Class A <	731.05
					Modular Concrete Block Retaining Wall: Class D or higher	732.05
					Drainage fill	732.05
					Temporary Wire-Faced Mechanically Stabilized Earth Retaining Walls: Class A or higher	735.05
Section 800					Traffic Signals: Class E or higher	805.02

Gradations shall be in accordance with 904.03 apart from the following:

** 904.05*

*** ITM 226*

Table B.2
Coarse Aggregate Use for INDOT #'s 9, 11/SC11, 12/SC12. (Section 904.03).

	INDOT # 9 **AASHTO None**		**INDOT # 11/11SC** **AASHTO M 43 - # 8**		**INDOT # 12/12SC** **AASHTO None**	
	Description	**Subsection**	**Description**	**Subsection**	**Description**	**Subsection**
Section 200	End bent Backfill: Crushed Stone or ACBF, Class D or higher Structure Backfill: Type 3	211.02 211.03 *	Structure Backfill: Type 3	211.03 *	Structure Backfill: Type 3	211.03 *
Section 400	Cover Aggregate (4/4P, 6/6P): Class B or higher	404.04	Seal Coat Cover Aggregate (3/3P, 5/5P, 6/6P, 7/7P): Class B or higher	404.04	Seal Coat Cover Aggregate (2/2P, 5/5P): Class B or higher Prime Coat Cover Aggregate: Class B or higher	404.04 405.04
Section 500			PCCP Partial Depth Patching: Class AP <	506.02	PCCP Joint Repair: Crushed Stone, Class A or higher	509.02
Section 700	Bridge Railings: Class B or higher Underdrains (4" and 6"): Class E or higher	706.02 718.02	Patching Concrete Structures & Repointing Masonry in Structures: Class A or higher Concrete Bridge Deck Overlays Latex Modified Concrete: Crushed Stone, Class A or higher	710.02 722.02		

Gradations shall be in accordance with 904.03 apart from the following:
** 904.05*

Table B.3
Coarse Aggregate Use for INDOT #'s SC16, 91, 93PG. (Section 904.03).

	INDOT # 16SC **AASHTO M 43 - # 89**		**INDOT # 91** **AASHTO None**		**INDOT # 93PG** **AASHTO None**	
	Description	**Subsection**	**Description**	**Subsection**	**Description**	**Subsection**
Section 400	Seal Coat Cover Aggregate (3/3P. 5/5P, 6/6P, 7/7P): Class B or higher	404.04				
Section 700			Precast Concrete & Precast Prestressed Concrete Structural Members: Class A or higher Reinforced Concrete Box Structures: Class A or higher Reinforced Concrete Three-Sided Structures: Class A or higher MSE Walls: Class A or higher Modular Concrete Block Retaining Wall: Class A or higher Temporary Wire-Faced Mechanically Stabilized Earth Retaining Walls: Class A or higher	707.02 714.02 723.02 731.05 732.05 735.05	MSE Walls: Class F or higher	731.05

Gradations shall be in accordance with 904.03

Table B.4
Coarse Aggregate Use for INDOT #'s 53, 73. (Section 904.03).

	INDOT # 53 AASHTO M 147 - Grade B		INDOT # 73 AASHTO M 147 - Grade C	
	Description	**Subsection**	**Description**	**Subsection**
Section 200	Embankment Without Stiffness Control	203.25	Geocell Confinement System	214.03
	Geotechnical Instrumentation: Class D or higher	204.02		
	Subgrade: Type IC, ID, II, IV, V	207.04		
	Geogrid Subbase	214.03		
	Geocell Confinement System	214.03		
Section 300	Aggregate Base: Class D or higher	301.02	Aggregate Pavements or Shoulders: Class D or higher	303.02
	PCCP Subbase Separation Layer: Class D or higher	302.02	Concrete Bases: Class D or higher	305.02
	Aggregate Pavements or Shoulders: Class D or higher	303.02		
	Concrete Bases: Class D or higher	305.02		
Section 600	Sidewalks, Curb Ramps, Steps, & Handrails: Class D or higher	604.02		
	HMA Sidewalk Bed Course	604.07		
	Curbing: Class D or higher	605.02		
	Reinforced Concrete Bridge Approaches: Class D or higher	609.02		
Section 700	Leveling Pad	732.05		
Section 800	Highway Illumination: Class D or higher	807.02	Traffic Controls for Construction & Maintenance Operations: Class D or higher	801.02
	Cast-in-Place Foundations	807.10		
	Precast Foundations	807.10		

Gradations shall be in accordance with 904.03

Appendix C. INDOT Fine Aggregate Gradation Summary of Application

Table C.1
Fine Aggregate Use for INDOT #'s 23, 24. (Section 904.02).

	INDOT # 23 AASHTO M 6		INDOT # 24 AASHTO M 29 - # 1	
	Description	**Subsection**	**Description**	**Subsection**
Section 200	Flowable Backfill	213.02	Flowable Backfill	213.02
Section 400	Seal Coat Cover Aggregate (1/1P)	404.04	Cover Aggregate	404.04
	Prime Coat Cover Aggregate	405.04	Prime Coat Cover Aggregate	405.04
	Sealing/Filling Cracks & Joints	408.02	Sealing/Filling Cracks & Joints	408.02
Section 500	PCCP	502.02	PCCP Restoration	507.02
	PCCP Patching	506.02	PCCP Joint Repair	509.02
	PCCP Restoration	507.02		
	PCCP Joint Repair	509.02		
	Joint Filler at Transverse Joints & Bottom Half Repairs	509.09		
Section 600	Sidewalks, Curb Ramps, Steps, & Handrails	604.02	Sidewalks, Curb Ramps, Steps, & Handrails	604.02
	Monuments, Markers, Parking Barriers	615.02		
	Riprap & Slope wall	616.02		
	Tree Root Protection	622.14		
Section 700	Structural Concrete	702.03		
	Construction Joints	702.15		
	Precast Concrete & Precast Prestressed Concrete Structural Members	707.02		
	Crack/Joint Filler Grout	707.09		
	Mortar Patching Concrete Structures & Repointing Masonry in Structures	710.02		
	Precast Concrete Wingwalls	714.06		
	Mortar Beds for Frames for Casting & Bearing Plates for Manholes	720.03		
	Placement of Structure Sections & Wingwalls	723.11		
	MSE Walls	731.05		
	Modular Concrete Block Retaining Wall	732.05		
	Temporary Wire-Faced Mechanically Stabilized Earth Retaining Walls	735.05		

Gradations shall be in accordance with 904.02

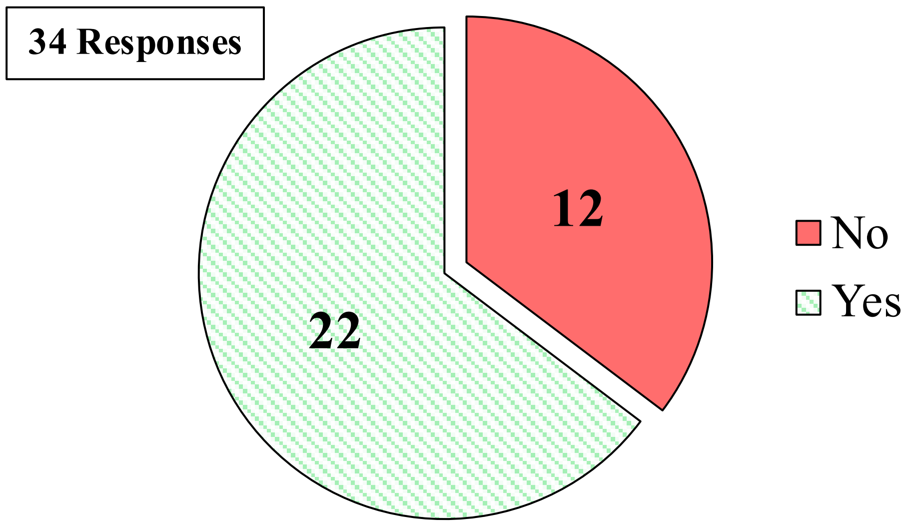
Table C.2
Fine Aggregate Use for INDOT #'s 15, 16, PP, S&I. (Section 904.02).

	INDOT # 15 AASHTO M 45 - Natural Sand		INDOT # PP AASHTO None		INDOT # 16 AASHTO M17		INDOT # S&I AASHTO None	
	Description	**Subsection**	**Description**	**Subsection**	**Description**	**Subsection**	**Description**	**Subsection**
Section 600	Sidewalks, Curb Ramps, Steps, & Handrails	604.02						
Section 700	Precast Concrete Wingwalls	714.06						
Section 900	Pneumatically Placed Mortar Mortar Sand	904.02 904.02	Pneumatically Placed Mortar	904.02	Mineral Filler for SMA	904.02	Snow & Ice Abrasives	904.02

Gradations shall be in accordance with 904.02

Appendix D. Aggregate Producers Survey Responses

1) Are there any general difficulties with having to switch between INDOT and AASHTO/ASTM/Other agency gradations?



1.1) If yes, please explain the difficulties faced.

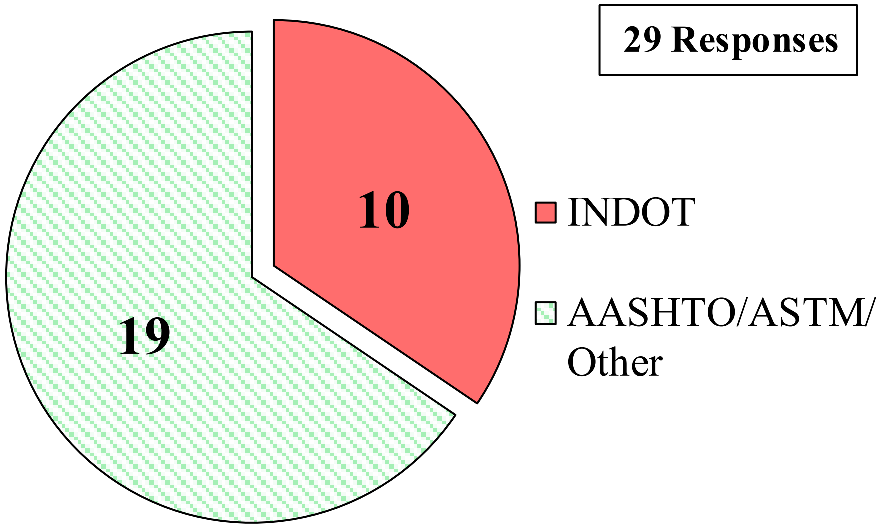
22 Responses

- The concern is that this includes overall quality parameters, not just gradation requirements. While adjusting gradations should be manageable, changes such as a tighter No. 200 limit for coarse aggregates or reduced deleterious material tolerances for fine aggregates could create challenges.
- Required Administrative changes would be difficult to manage and would take a lot of time to complete. Training and familiarization by operations, sales, quality control and even administration groups would take time to implement.
- If all three remain in place, in the marketplace, it could require changes in plant set-up between InDOT and ASTM/AASHTO material runs.
- Occasionally we get into some production headwinds with FAA materials-
- Having to chance different processing equipment
- Having to fit gradation specs of AASHTO products requested from customers in surrounding states (ODOT & MDOT) with what we produce in INDOT spec.
- Our gradation software would need to be revamped. Signage on stockpiles would need to be replaced. Sales haul truck scale system would need revised.
- We strive to optimize our plants consistency and gradations. At locations where we do serve multiple jurisdictions this causes us to have extra stockpiles to segregate the different

products. When we can we try to make our product where it meets multiple jurisdictions specifications it may not be in the center of the standard specs, we may have to move our master bands further away from the center of a product.

- Having to switch back and forth presents the problem of having adequate stockpile space as all finished products will need to be segregated
- It has required additional quality testing, signage, stockpiling and sampling to ensure we are meeting the requirements of 2 different entities.
- Plant changes to include but not limited to: screens, crusher settings,
- Difficulty with contractors and engineers from other states and agencies agreeing with specific specifications.
- No, If switching from INDOT to AASHTO / ASTM.
- If asking about running multiple specs then Yes because of stockpiling, screen changes, multiple QC test, charting etc
- storage areas or stockpile space would be an issue to keep multiple gradation stockpiles
- Yes especially in the Louisville Metro Area, get a lot of business from Kentucky and have to keep multiple stockpiles in order to operate.
- NO. I feel like if INDOT would go to this direction from a aggregate supply side it would be easier for us to make a more consistent quality product with less segregation concerns.
- Different Gradations require different piles of aggregate.
- Changing to AASHTO sizes would definitely be a benefit for Mulzer Crushed Stone, as we provide materials to Kentucky, Ohio and West Virginia. Inventory space is always an issue with maintaining INDOT and AASHTO stockpiles, my example would be AASHTO #67 and INDOT #8, practically the same material, but just enough specification difference to require a stockpile of each size.
- Many of the gradations are similar but producing for both INDOT and AASHTO does require close attention to the gradation ranges. Producing to meet both specs simultaneously shrinks the gradation bands. If a product cannot be produced to meet both specs i.e. INDOT 12 vs AASHTO 78, some customers prefer AASHTO 57s to be 100% passing 1”while INDOT 5s require 98% max, separate stockpiles must be maintained.
- time and material wastage when switching gradations

2) **Which gradation is easier to produce — INDOT or AASHTO/ASTM/Other standards?**



"Other" listed in Question 2

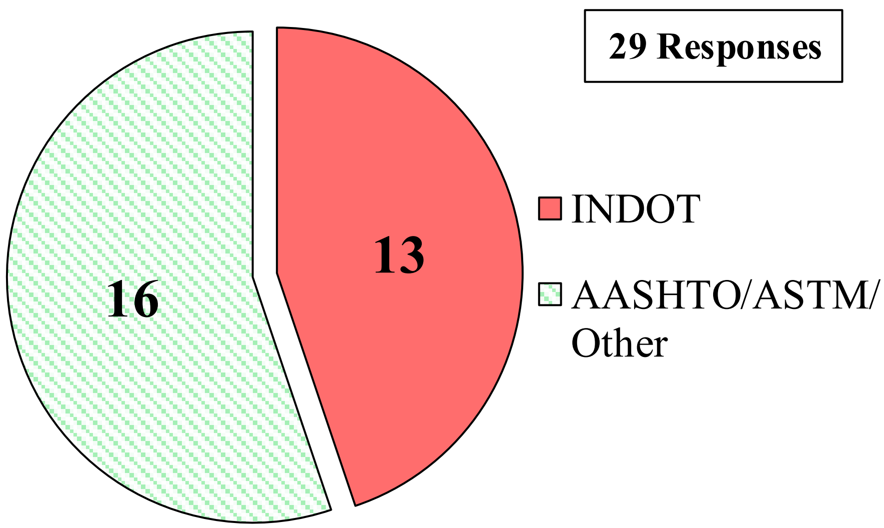
18 Responses

- INDOT has QA option
- Cleaner
- Easier
- I wouldn't say one is easier than the other to produce. We can make any product, the challenge comes more in the overall product mix.
- AASHTO
- Neither is easier than the other
- It depends on the product.
- Other
- AASHTO/ASTM
- Less segregation
- AASHTO
- AASHTO/ASTM easier
- 57s and 67s
- INDOT specifications sometimes have sieves that work against one another. An example would be INDOT #8's. With a the critical sieve being the 1/2" with a specification 40-70 and the 3/4" sieve being 75-95, if the critical sieve falls in the middle of the specification, such

as 55 percent it can be difficult to keep the 3/4" sieve below max. of 95 percent. The AASHTO sizes have less of these Challeges.

- ASTM
- ASTM
- Varies by product
- just because it is the same as adjoining states

2.1) Which gradation is more economical to produce—INDOT or AASHTO/ASTM/Other standards?



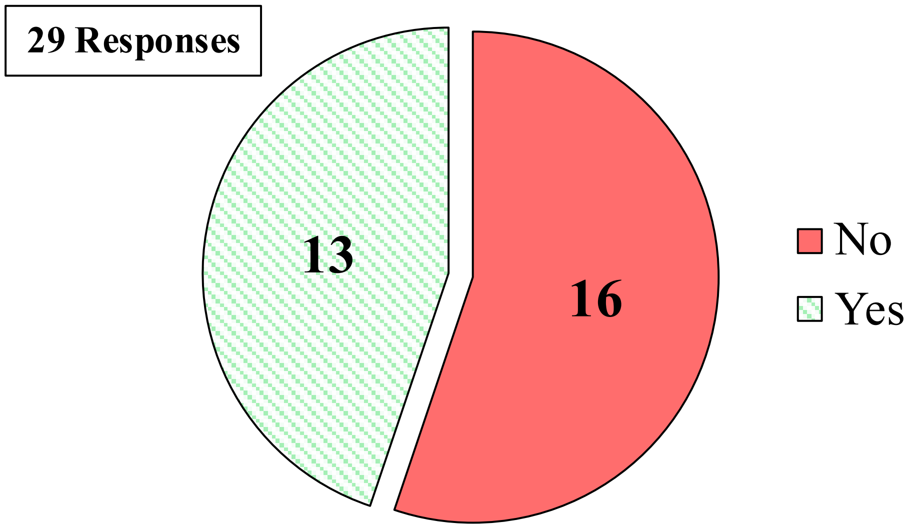
"Other" listed in Question 2.1.

15 Responses

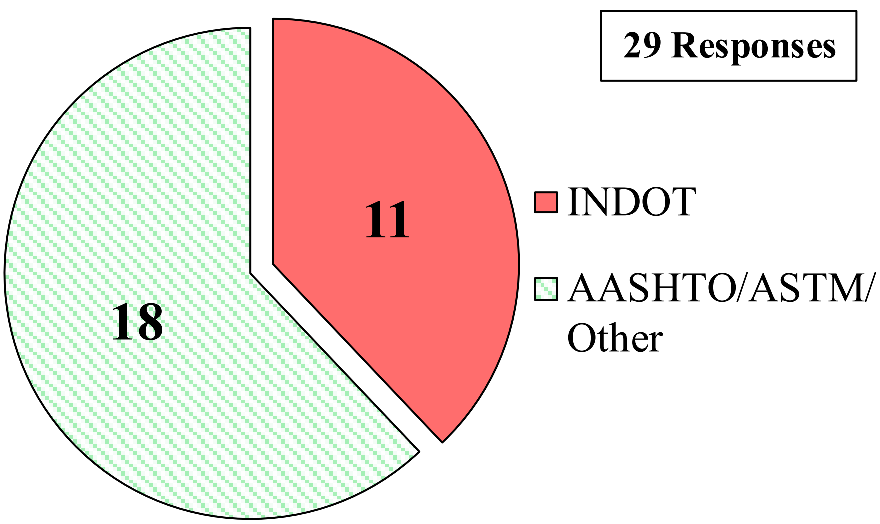
- More economical
- Commercial does not require documentation
- AASHTO
- Neither is more economical than the other
- Other
- AASHTO/ASTM
- Less plant adjustments
- AASHTO
- AASHTO/ASTM more
- 57s
- Quicker and easier products to fine tune to targets.

- ASTM
- ASTM
- Varies by product
- Same

2.2) Does the ease or cost of producing these gradations depend on geographic location?



2.3) From a manufacturing perspective, which gradation is more practical to produce?



3) **Briefly describe the QC process involved when producing aggregates to satisfy a specified gradation.**

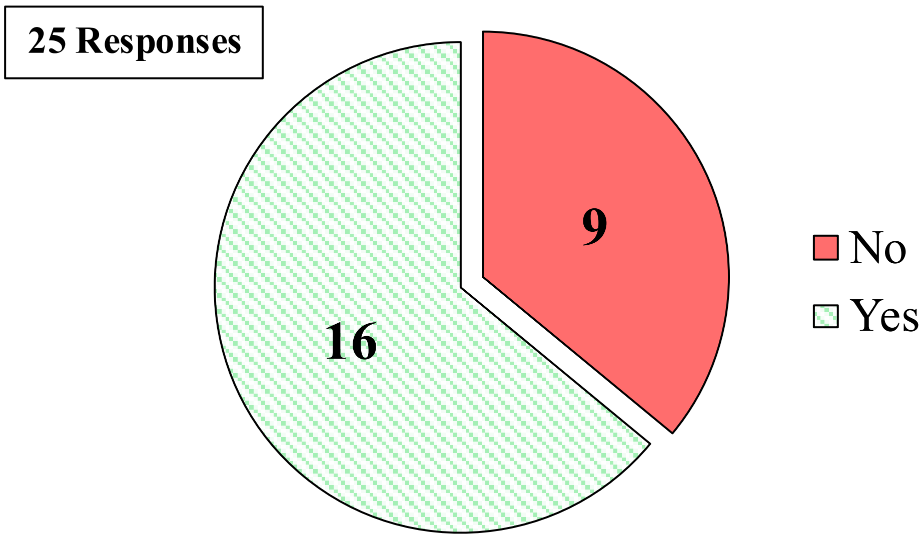
24 Responses

- To achieve the desired aggregate gradation, the following adjustments may be required: crusher settings, screen modifications, gate changes, and washing.
- Sample material. Perform required tests. Obtain results to confirm product is within required specification range,or in the case of "critical Sieve" products (coarse graded) confirm critical sieve is in close proximity to designated target. Report results to Operations, recommend changes, if needed, to process.
- QC samples ongoing production cones as well as stockpiles and shipping cones for awareness of the plant production. Notifications to appropriate management as needed.
- Ensuring the plant is set up appropriately to make the specific aggregate and then following INDOT testing procedures to make sure the product meets INDOT specifications.
- Blasted and mined from the correct location in the deposit. Plant shut down and reconfigured with proper screens to produce the requested gradation. Numerous samples are conducted in the beginning to make sure the plant is running at the right speed and the screens are screening as expected. Stockpiling of said product is performed properly. Loader operators are retrieving the finished product in a manner that protects the integrity of the final gradation requested to be shipped.
- For INDOT products test and verify gradation at INDOT specified intervals
- In aiming for a most consistent product the best practice should be to design the master band off what the plant wants to make. Each plant is different and has its own challenges, and when we try to force a plant to make a specific gradation consistency generally suffers. The process is really a trial and retry to make changes to the plant without changing other products being produced. If the plant doesn't want to do it, we generally have to find tricks or modification to factory equipment to make the product in spec.
- The screen setup of a plant is determined by the bounds of the target gradation. After the initial production of a material, it is sampled as per ITM 207 and tested for gradation. If the results of the gradation are not on target, minor changes (such as changing the direction of the shaker or diverting material using gates) or major changes (such as changing screens on the plant) will be made. The minor tweaks to the plant are usually made first, unless the initial results are very far from being passing material.
- As it is now, when we produce INDOT spec aggregate, it may or may not be the same as the AASHTO spec, therefore, we have to maintain a separate stockpile for basically the same material on the slim chance it doesn't meet spec one way or the other. INDOT following the

AASHTO spec would allow bigger stockpile area, less waste, perhaps as well as better built stockpiles because there aren't smaller INDIANA ONLY designated piles laid out everywhere.

- Different screen setups, feed moisture, and coarse to fine feed all play factors in producing a quality product. The screen setups ups will dictate meeting INDOT or AASHTO/ASTM specs.
- See if you have made anything similar to the needed gradation and adjust screens/plant from there.
- No significant changes than when producing INDOT requirements.
- Trial and error
- Obtain samples every 2000 ton produced spit, dry, wash and dry put into sieves and run gradation to see if it meets specs
- Our production facilities are dialed in on INDOT Standards/Specs. When having to switch to a different Standard/Spec that could include changing screens, changing crusher settings. It could slow the process down (TPH). It could make it difficult for all produces to participate with this (ex: IMI 8s), not everyone can make those. Another example is not everyone can produce a PRA limestone material. Due to plant setup or geological area.
- QC may advise screen settings to plant personal, make door adjustments to divert material sizes as needed through chutes to other products to bring materials into spec. While monitoring for decants, production cone segregation / handling, then any increased decants happening from material degradation.
- AASHTO / ASTM 57 with 25 - 60% passing the -1/2” sieve. With less fines passing the -1/2” less concerns with stockpile segregation, high decants or increased material degradation.
- crusher adjustments. crusher speeds are adjusted by a VFD. possible screen media changes. adjustments gates in the material chutes.
- First you need to become a CAPP source which requires a series of different tests. Once approved you can begin producing aggregate to sell in industry. There are specific frequencies at which products need to be tested. If those needs are met the producer can test more frequently to meet their QA/QC requirements or a customer.
- Historically, we have seen when you have a significant weather event or change in season it is important to test.
- We start the aggregate on the County pile until the specified gradation is reached during testing.
- Plant setup for the particular products, startup, check gradation of products, make adjustments to fine tune each product to specific targets.
- Crusher adjustments, screen setup, gates and doors

4) Are production tolerances different when producing INDOT and AASHTO/ASTM/Other gradations?



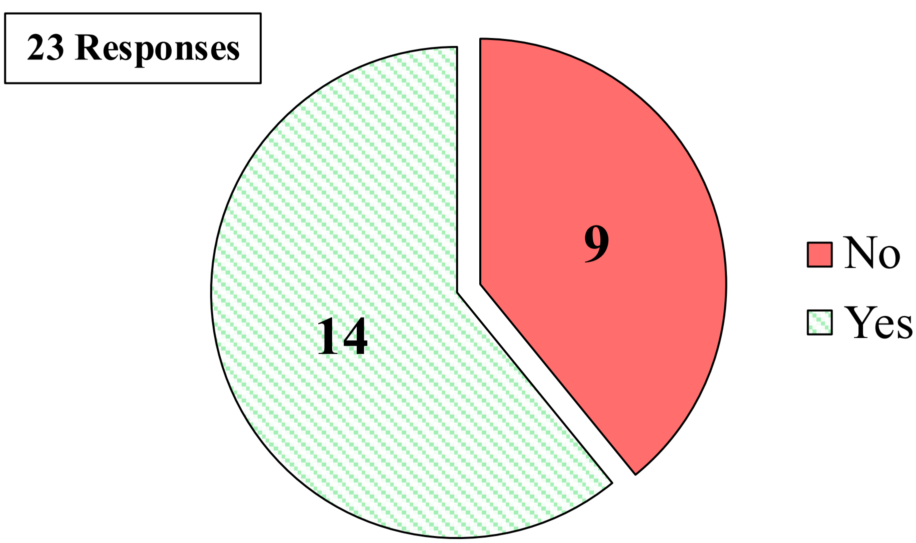
4.1) If yes, briefly explain the differences.

16 Responses

- I would need to review the AASHTO methods in more detail, but INDOT requires critical sieve compliance for coarse aggregates, which is more stringent than the AASHTO ranges.
- The sieves themselves may be different than a like sized INDOT product. Within the same sieves, the ranges are typically different as well.
- QA tolerances are established by the customer, and commercial products are what we specify
- Standard specs generally give us a wider starting target, but then we impose a masterband to control it just the same. Our customers are more of a driver over specs and are more demanding of consistency than ever.
- Sometimes, the processing procedures have to differ to make one or the other, following, one spec, would reduce plant downtime, resulting in a more consistent product with greater inventory to meet customer demand.
- Both have tolerance that are somewhat similar just on different sieves for comparable products.
- It depends on the contract since for us these AASHTO gradations are usually used in government work so QC requirements will be spelled out in the contract.
- No use of standard deviation. Make a consistent product for customer needs is most critical. Customer able to adjust any and all aggregates to meet JMF requirements.

- Different specifications
- Similar answer as Question 3
- INDOT you have to be mindful of breakdown, fines increase, decant, segregation. AASHTO / ASTM less of a concern because we are not flooded with fines from the beginning, then have to worry about the additional from the above.
- production tonnage variations have less of an impact
- In Kentucky, for example, we do not have to adhere to as tight of a target when producing AASHTO / ASTM stone, meaning, the customer generally tells us where they like it and that what we shoot for.
- The AASHTO gradations require less sieves on the 67s and 57s compared to the 8s or 5s.
- ASTM gradations allow production of 57s and 8s at a higher production Volume. INDOT ST8s and St11s will be produced at a slower rate do to all the fines that are needed within the gradations.
- INDOT is somewhat unique in its control requirements. Many other states expect the contractor to interact with the producer directly regarding gradation consistency.
- min. max. range per sieve varies between the specifying agency. Some agencies have tighter tolerances than others.

5) **When producing a specific aggregate size, is the midpoint of the specified gradation range typically used as the target value?**

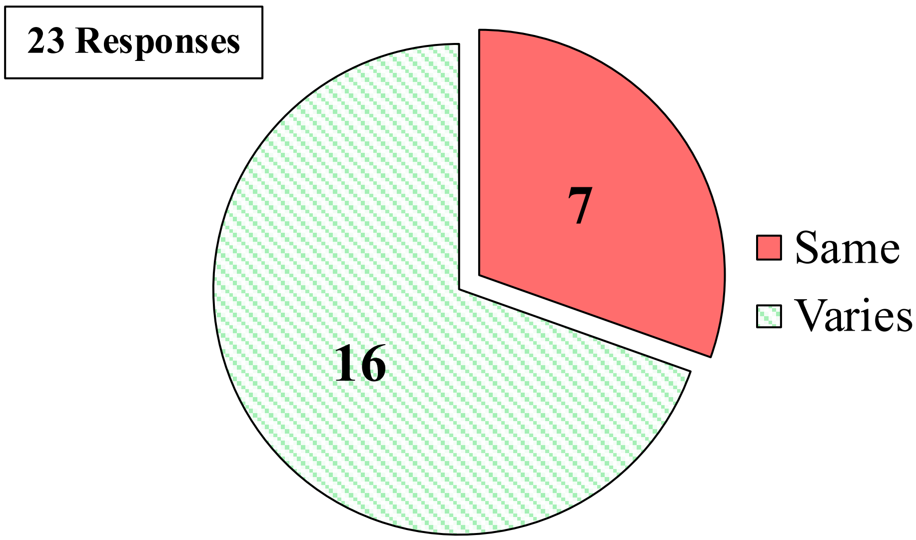


5.1) If not, what is it?

11 Responses

- Yes and no. Depending on the product size and if the product requires the use of a critical sieve (coarse graded sizes typically do) the CAPP program encourages placement of the target somewhat centered in the middle of the specification range for only the critical sieve required for that product size. Dense graded and fine aggregates have no target requirement.
- We look at all sieves
- In many instances, the midpoint is considered the target value. There are also several materials which have a target value on the critical screen chosen by taking the average value on that screen after the first 5000 tons of material have been chosen. This can reduce variability by working with each individual plant's ability.
- This is typically the case. Sometimes there is another sieves that can control the bottom portion of the gradation that is not directly the middle sieve though.
- It could be based off of how your plant runs. Could be making for more than one State Spec and the midpoint could be different.
- For certain products on various sieves we prefer to run down the middle, for other sieves we may tend to stay on the bottom end, for the critical sieve we tend to run on the coarser side for most products because of the concern of higher decants, stockpile segregation concerns, or material degradation.
- depending on the material it tends to be on the lower end for larger material and on the upper end for smaller material
- Just depends on the job / customer.
- However, some customers ask for different targets. If a customer does request this, it is advantageous for the producer to try and meet this specification/target.
- The capabilities of the plant must be considered; the plant may not be capable of producing the “fines” needed to use the mid-point as the target.
- Varies depending on the aggregate mix being produced. Coarse aggregates may trend toward the lower end of the specification to maximize production of Finer aggregates.

6) **Are the produced gradations the same for all customers or do they vary based on customer requests?**



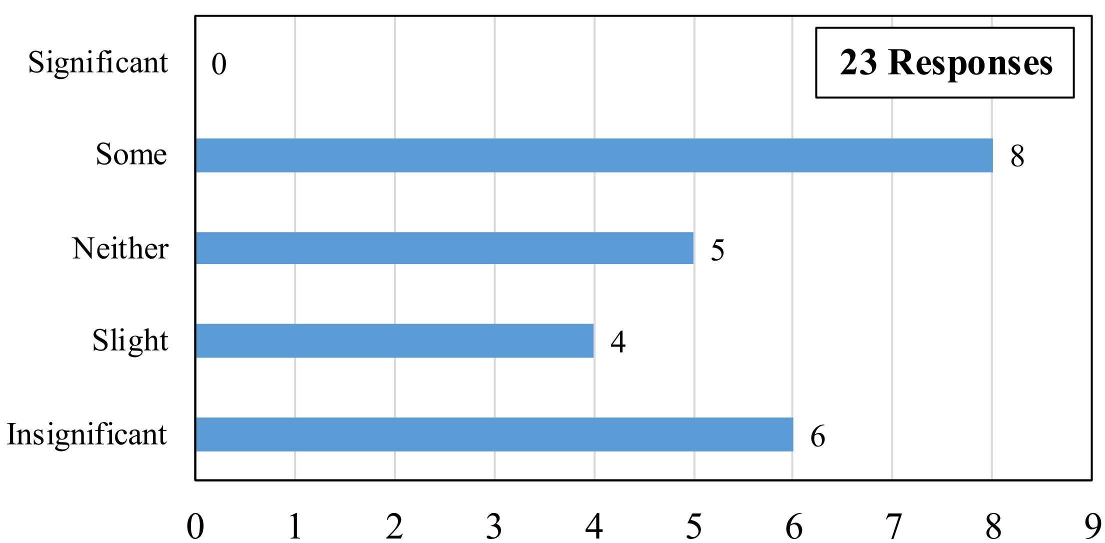
6.1) **If they vary, please elaborate.**

17 Responses

- Essentially the same, but there are some differences in coarse aggregate requirements for concrete compared to HMA.
- Typically, yes. Although a specific gradation may be requested by a given customer, but that product would be sold to other customers if suitable to their needs. Hence, on reason for the use of QA application. In very few cases will a plant produce a specific product used by only one customer.
- At times a customer may need a product a certain way because it lends them a better end product based on their designed mixture.
- Gradations are dependent upon what the paying customer wants and needs
- We have had customers ask for materials shipped to them be on the finer or coarser end of the spec. This does not happen often, but it does happen.
- The INDOT gradations are all done to the same specifications. There are some variations of the material which are sold to customers as commercial (Non-state approved) based on their requests.
- Sometimes, customers need a product that may differ somewhat from what everyone else may be wanting or needing. In a perfect world, the gradations would be the same across the board.

- If you are located on state lines, customers from different states can need different products. Even within the same state, some customers are more tolerant than others with certain products like washed sand.
- Whomever is doing the mix design has on occasion came back and asked for a material gradation adjustment because other products can not be adjusted and are the ones approved for the contract.
- Different customers in different states have a preference.
- We lock in what gradation works best for our key customers and for our plant / site.
- Some jobs may want a coarser product, whereas others may want the gradation to be finer
- As previously stated, customers typically have different requests based on application of the material and mix designs.
- There are situations where a customer will have specific gradation request, but that is not typical.
- We have customers that request 57s request coarse St8s because they don't want all the fines that the ST8 gradation includes.
- Some customers request AASHTO 57s 100% passing the 1” while others will accept 100% passing 1 1/2”. Majority of customers value consistency over specific gradation as long as gaps in the gradation do not occur.
- minor tweaks within specified ranges are accommodated based on the need and application

7) INDOT specifies a No. 30 sieve, while AASHTO uses a No. 50 sieve in certain gradations. What impact do such differences in specified sieves have on aggregate production?



7.1) Briefly describe the potential implications of specifying different sieves (e.g., No. 30 vs. No. 50) on aggregate production and quality control of the final gradation.

23 Responses

- The #30 and #50 sieves are already tested on INDOT fine aggregates, so this shouldn't pose an issue.
- It is typically not an issue. In Dense graded products equivalent to INDOT 53, plants will produce a "53", include a
- #50 sieve in the analysis, and as long as the final results meet both state gradation requirements all is good. The offset in gradation/sieve specifications will typically accommodate for this. This happens all the time with Illinois boarder sources. If the entire Midwest switched to AASHTO gradation bands, the simple switching from the 30 to the 50 would be no issue as long as there is a reasonable offset to required sieve range.
- These finer particles in a product are much more difficult to control with plant adjustments. Sometimes a producer is at the mercy of mother nature.
- this could have minimal implications when the product is being blended with natural or man sand
- Its not as much which sieve we choose, but how many of the sieves have specs on them. The plant is not as versatile as people may think
- The different sieve specification could potentially cause problems if you are trying to have one material that can be sold as several different products. Generally, if the demand for both products is great enough, the production will be changed to make to separate materials.
- i think if the product was well graded, there may not be that many problems switching focus from one to the other in most cases
- If the specification is known beforehand, changes to screen setups and other aspects such as crusher speed can be made prior to production to meet the given specifications
- I personally have not had this sieve be a gradation difference but aside from just making sure that you have the No. 50 in the lab and needing to have a history of results on that sieve it would make it easier if everyone asked for the same thing.
- Depends on the product and requirements. Both sieves are generally included in the next of sieves we use when testing.
- n/a
- i think using the 30 would help from compacted aggregate from becoming to plastic
- Clients could be impacted.
- If not following then it could have some differences, some sieves or certain products could be impacted greatly by slight changes, good or bad.
- I dont believe it will have a large impact

- There is always going to be a little bit of a learning curve, but most of the typical products, Ie INDOT 8's and AASHTO 57's use the same sieves, just with different specs. On the products that are different, it shouldn't be a far stretch to say that a plant couldn't adapt to a specific specification.
- I have only had a few customers ask to meet a specific AASHTO gradation. Many of these come from private sector work in the environmental area.
- I don't think it makes a difference.
- Due to our production for multiple states, this is normal and should create little or no implications.
- No issue
- Having both requirements tightens the gradation on sieves which can only be adjusted through wet processing.
- Very minor, gradation tends to track the same, If the 30 falls usually the 50 will fall as well fairly proportionally

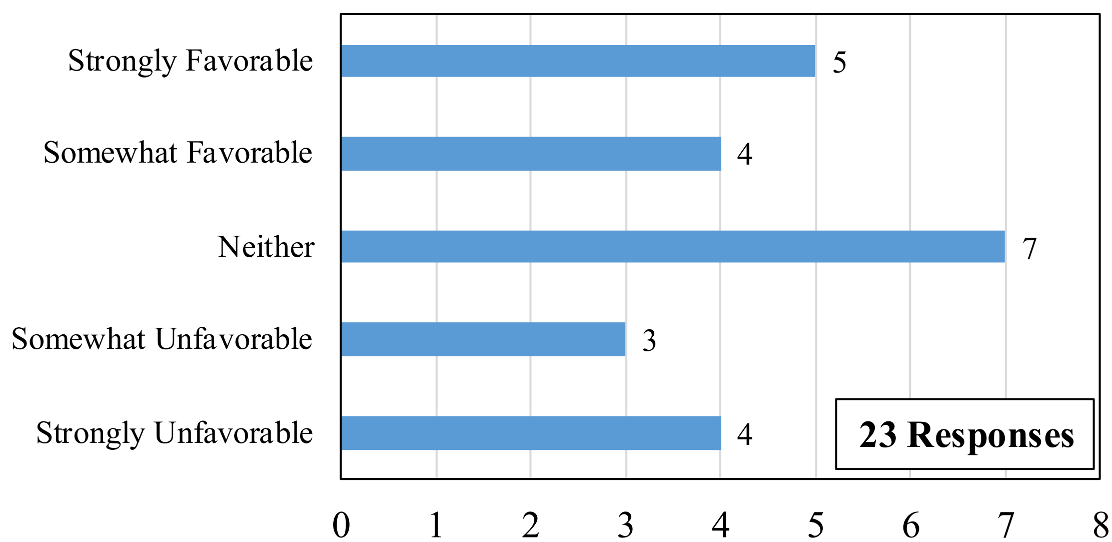
8) What non-INDOT (other agency/specifier) aggregate gradations do you produce in Indiana?

22 Responses

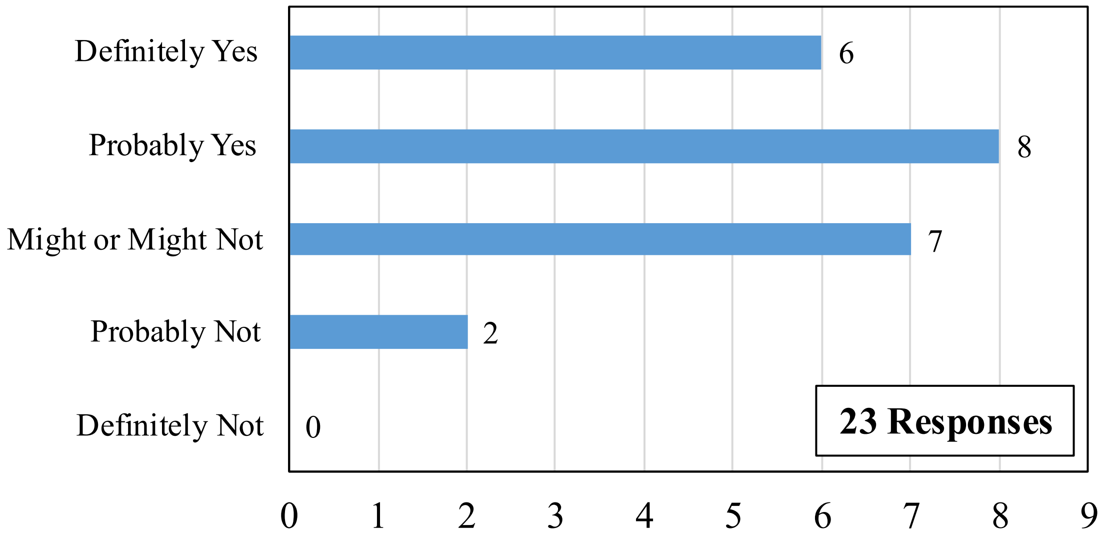
- None
- FAA, AREMA, ACE, Solar and wind energy
- Illinois, Ohio, Kentucky
- Commercial products
- Not really any produced in Indiana, we do produce Indiana products at our Thornton location where we do produce to different agencies. Thornton produces a variety of Illinois specifications (CA 1,3,5,7,10,11,13,16,20,21,22), ASTM 4 and 467 at times, Army Core Armour Stone, ASTM 67
- 1,3,5,7,10,11,13,16,20,21,22), ASTM 4 and 467 at times, Army Core Armour Stone, ASTM 67
- Kentucky, Illinois, AASHTO.
- Michigan DOT products
- ASTM 57, ASTM 4
- Illinois, Michigan, Ohio, Pennsylvania, NY and Ontario. AREMA
- None
- None
- Illinois, Kentucky, Ohio
- 57, P209

- ASTM 57
- KYTC, ODOT which are both primarily AASHTO gradations,
- ASTM 57
- KYTC, ODOT which are both primarily AASHTO gradations,
- Illinois
- 67, 57, 8, 304, 617, 467, 9M, 3, and DGA
- WVDOH, ODOT, KYTC, PADOT and Corp. of Eng.
- 78 which is similar to a 57, QA4 contains no fines,
- Kentucky, Ohio, Pennsylvania, West Virginia, FAA, Army Corp of Engineers
- currently none but have made #57 and 304

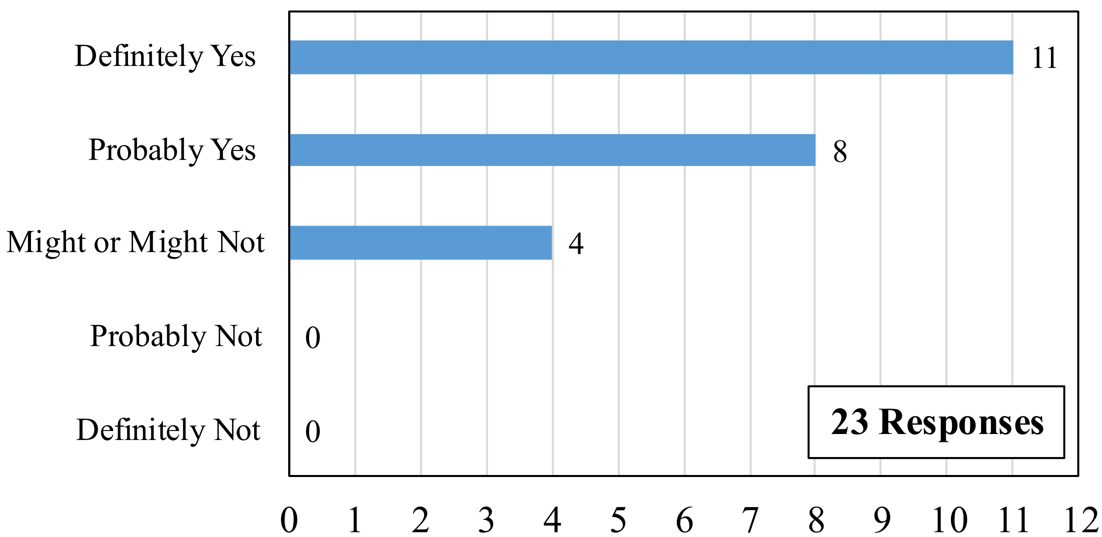
9) Overall, from a producer's perspective, what would the reaction be if INDOT adopted AASHTO gradations?



9.1) Is this even feasible?



9.2) Is this more favorable for aggregate producers that operate in multiple states?



9.3) Please briefly describe the estimated economic impact of such a change.

22 Responses

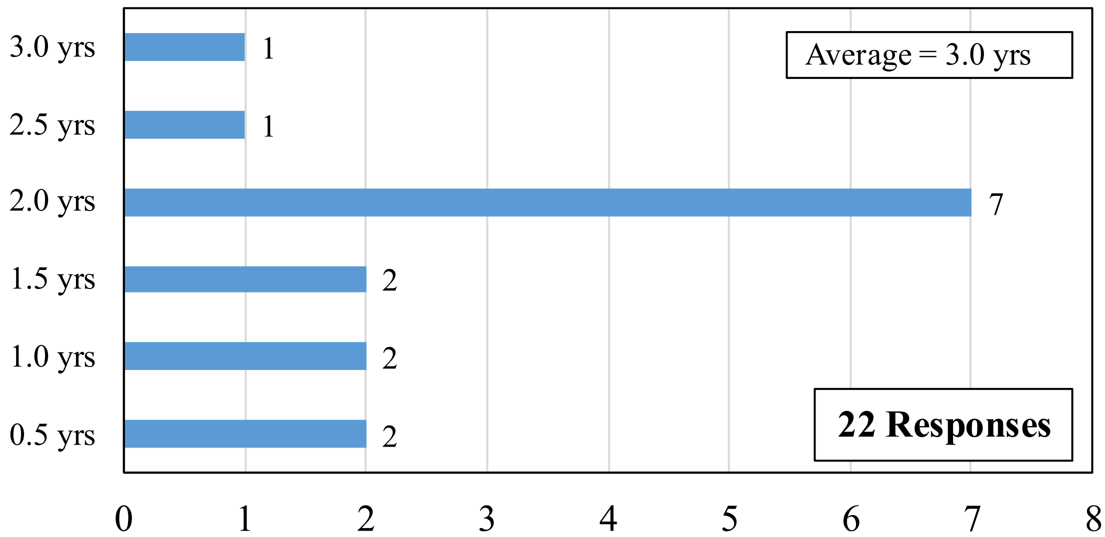
- Uncertain
- From a training and administrative change point of view the economic impact would be considerable. But, let qualify my answers 9.0, 9.1, 9.2.

- 9.0-This is not my point of view, but the industry in general panics with change. This industry is familiar with current products. Operations have developed tried and true methods for plant set up that work. Thus, the initial threat of change may create unwarranted stress on some.
- 9.1-It is feasible. This would help align with 2 of the neighboring states, but more importantly, Federal agencies and national companies that rely on AASHTO/ASTM nomenclature (the Walmart's of the world).
- 9.2- Absolutely, as long as it's not Illinois or Michigan
- I'm honestly not equipped to answer this question, but I assume it could be significant.
- No real impact on us. We would simply need to modify our gradation tolerances and continue as normal
- No real impact on us. We would simply need to modify our gradation tolerances and continue as normal
- Its hard to say until we attempt, but there would need to be screen and other plant changes. We would have materials that were already produced that would not meet the new spec. It could go smooth trying to make the new gradations, or it could take us days to weeks to get our plants back tuned out to run at the new gradations consistently. If it just doesn't work at a specific plant the dollar amount could be huge in trying to adapt and new equipment requirements
- It would cause all products produced to revert to their "start-of-production" phase, which means that every product would have to have new screen setups in production. Every product would also have to be tested much more often initially. So in the short term, it would cause significant production delays. All of the material stockpiled would also have to be either sold or reclassified, so it might be difficult to find room for all new products, which could not be stockpiled together with the old gradations. There would also have to be all new contracts with customers regarding which products they will be getting (as they would also have to change their mix designs to accommodate the new gradations).
- As described above, time savings plus better use of stockpile space creates a better, more plentiful product
- As described above, time savings plus better use of stockpile space creates a better, more plentiful product
- There would be a small economic impact as producers would need to purchase screens and backup screens to make sure they can meet the newly required specifications if they do not currently produce AASHTO/ASTM spec products at that location.
- There will need to be a change over time where producers could still be able to sell the INDOT material and deplete their stockpiles some of which are quiet large at some locations. Maybe that inventory could be sold as a grandfathered in material. The biggest expense

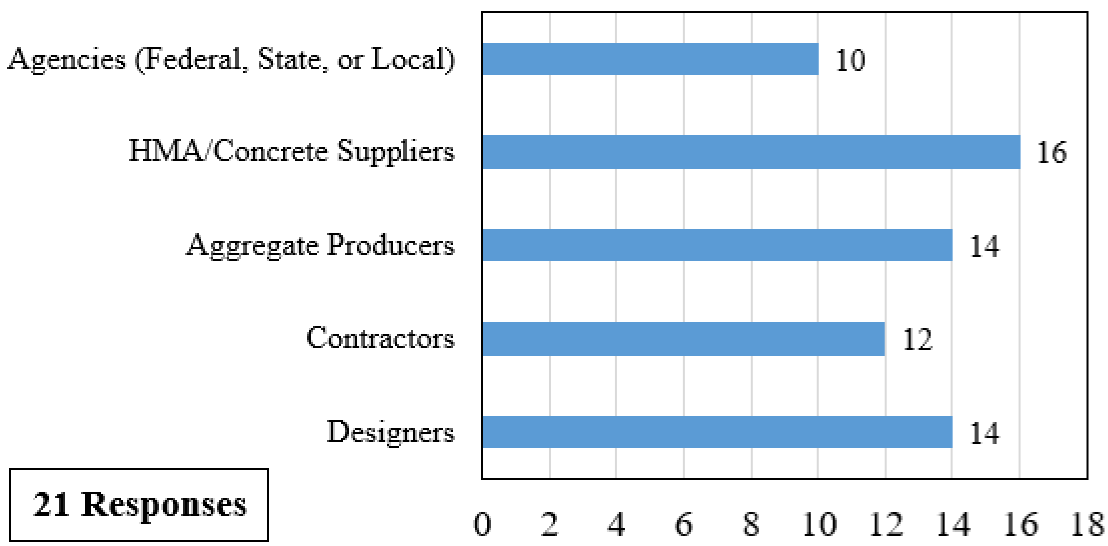
would be in plant changes, increased washing and/or screen size adjustments and then the extra QC work of testing and approval plus stockpile room. I truly don't have any idea what that would look like cost wise. I do believe that the “new to INDOT” products would have to be brought on 1 2 at a time so as to allow that change and cost to be spread out.

- Unknown.
- It will take a lot of time for the change and customers will be very confused
- it would be hard to put a number to at this time but would cost more in time and material
- Depends on if the production slows down due to changed TPH. Depends on crushers having to be switched out.
- I can see it helping with some of the current issues we deal with daily to counteract INDOT finer gradation specs. We spend alot of focus on our INDOT 8s to keep them in all aspects from production to the point of reaching the customer. For the most part our 11/12s are not as big of an issue unless we have carryover. If we were to adopt the AASHTO / ASTM Specs we would have to adjust our mindset on our screening processes & plant setups to maximize how to keep balance on the screens, but I am sure we can do it. In my mind, the benefits outweigh the challenge.
- Not sure.
- I cant speak on the economics of this change
- As producers we have significant cost associated with producing a state spec product. Small changes that would need to be made to meet this would require producers to do significant testing, change plant set up, and have a market for failing material. Additionally, HMA and concrete suppliers would likely need to reevaluate all mix designs and resubmit them to the state for approval. This could impact construction schedules significantly.
- I do not see a significant economic impact for such a change.
- Higher production volumes of the ASTM 8s/ IND 11s.
- $0 we do not price based on agency. It would have beneficial impacts on product availability, storage requirements and reduce off-spec material associated with product changes.
- Would have a very small impact

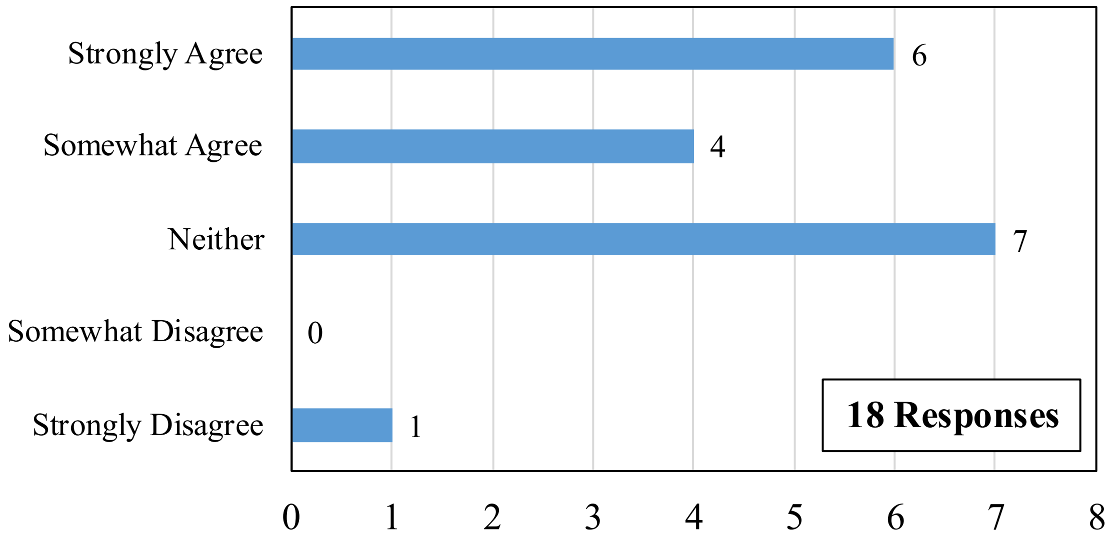
10) **What would be an ideal transition time period if AASHTO gradations was adopted?**



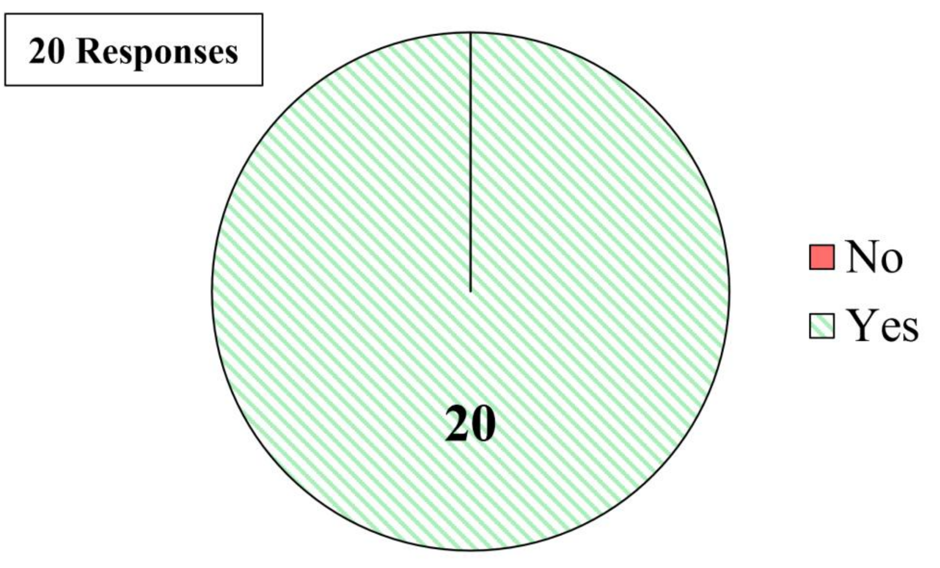
11) **Which stakeholders are most likely to be interested in (or impacted by) the adoption of AASHTO gradation?**



12) **The following questions are "to the best of your knowledge." If you don't know or don't have an opinion, you can refrain from answering. Would AASHTO gradations satisfy all INDOT needs?**



13) **Is adoption of AASHTO gradations more practical for aggregate producers serving multiple states?**



14) Are you aware of the historical background as to why Ohio and Kentucky use AASHTO, but Indiana has their own gradations?

18 Responses

- No
- no
- No
- No
- No, I am not aware of that background.
- No
- No
- No
- No
- No
- No
- No
- No
- No
- Historically they didn't have contractors from other states bidding jobs in Indiana
- No
- No
- Want to be different! :)

15) To your knowledge, are there any states who have recently transitioned or are considering switching to AASHTO gradations?

14 Responses

- Not that I am aware of
- No
- Not to my knowledge.
- No
- No
- No
- No
- Indiana
- No
- No

- Not sure
- No
- No
- No

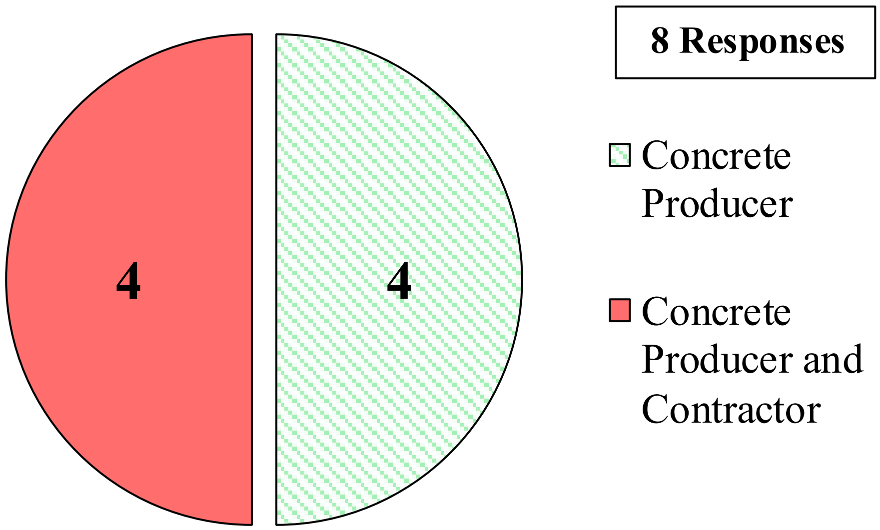
16) **Please feel free to provide any other feedback, comments, or suggestions you might have thus far.**

7 Responses

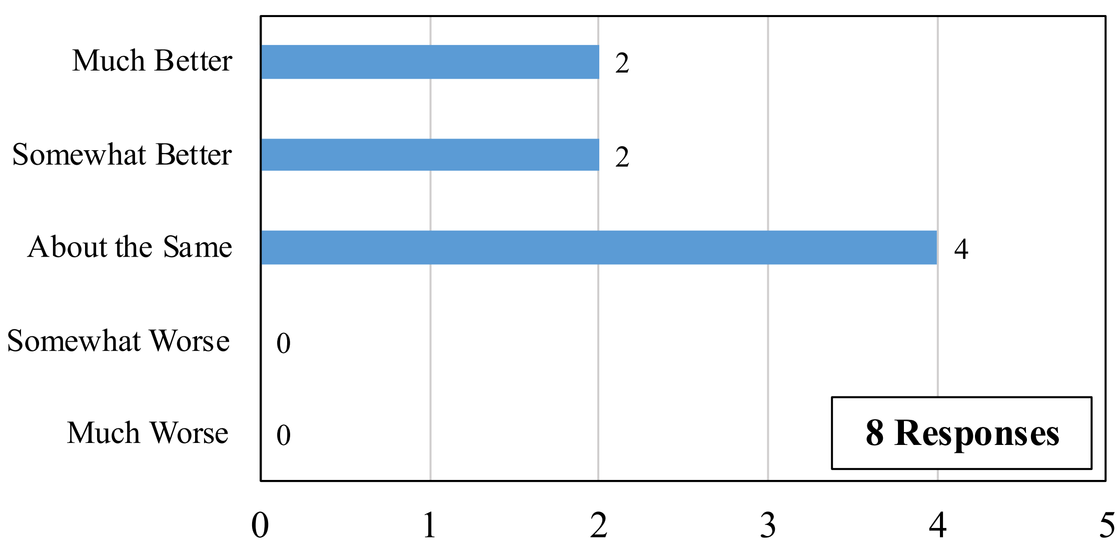
- Will this involve just gradations, or are quality parameters included as well? From a gradation perspective, my main concern would be any changes to the #200 sieve or decant.
- Move away from statistical acceptance of materials when produced. The product changes from production to shipping where shipping is more representative of what our customers are receiving. We find our customers biggest concern is consistency. If we could run our product with a very low standard at always below the target line, we have to document or make changes at the plant.
- I think this would be a very large step for INDOT, would be a large initial hurdle for Aggregate, HMA & Concrete Suppliers, but I believe all would benefit greatly in the end. I have been in the industry nearly 30 years with certifications in HMA, CAPP, former Concrete ; while spending 16 years on the HMA & 12 years with an Aggregate producer I can say that I would not have an issue from either side with the specification change. I feel that managing the product in the aggregate production phase will be easier to control or adjust, easier in managing stockpiles at the producer as well as the HMA / Concrete plant will be better with less concerns of segregation, which will most likely lead to a more consistent product gradation in use, then blending through plant bins will be easier to control with gradation consistency, which in turn could make for a better controlled HMA / Concrete finished product.
- I believe the way it stands is the best way. Unless neighboring states were open to the idea of adopting this, I do not believe it has any real benefit to suppliers, producers, or customers.
- For a river quarry this change would be greatly appreciated.
- ASTM/ASSHTO gradations will set Indiana in alignment with the Standard Aggregates which are used in multiple states.
- If AASHTO gradations are accepted, we should maintain the QA program to allow unique products to be produced based on contractor need.

Appendix E. Concrete Industry Stakeholders Survey Responses

Please select the category that best describes your primary line of business:



1) **DOTs in states like Ohio and Kentucky use AASHTO or ASTM gradations, while Michigan and Illinois follow their own state-specific standards. Other specifiers, such as the FAA or commercial clients, may also require unique gradations. In your opinion, how do these alternative gradations compare to INDOT's standard gradations for concrete production or base/backfill applications?**



1.1) Please elaborate on potential drawbacks of switching from INDOT's standard gradation to these alternative gradations.

8 Responses

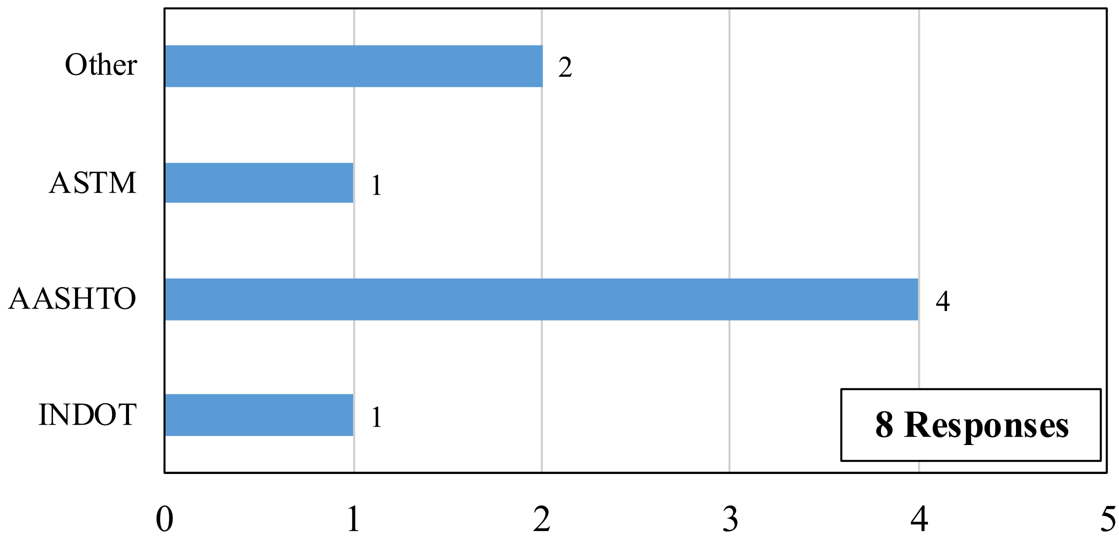
- There is no drawback from a material perspective. However, the aggregate industry is extremely resistant to change and chooses to maximize production toward premium products that tend to have a finer gradation.
- Making the change
- AASHTO/ASTM gradations can tend to have wider ranges resulting in situations where quality of product can be negatively affected.
- Making the switch in general will be a bit of a process, Some standards are not as stringent. in some cases the higher standard is needed for quality.
- None
- Quarries that do business outside of Indiana have a difficult time adapting to the ASTM/AASHTO gradations. For example an INDOT 8 can never truly be a 57 since the 57 can contain 1" aggregate. Also the decant or minus 200 is lower in the ASTM and AASHTO
- Potentially aggregate producer making INDot #8's and #57's at the same time.
- None except administrative cleanup

1.2) Please elaborate on potential benefits of switching from INDOT's standard gradation to these alternative gradations.

8 Responses

- INDOT's primary concrete coarse aggregate is a custom gradation called #8. As produced by most suppliers the product tends to be low on the 3/4-inch material and heavy on 1/2-inch material. INDOT needs a coarser primary aggregate for concrete.
- They will be closer to the surrounding sates
- Some commercial and FAA gradations drift into the 'difficult' category to produce and utilize in a large volume application. The quality can and usually is better but at a drawback of efficient/cost effective production.
- Ease of language in contracting, standard when crossing from state to state with projects.
- None
- Since switching to the Tarantula curve the intial gradations are not as important as the final blend in the concrete mix. It should be noted that the tarantula curve is for pavement only.
- Standardization across state lines.
- Simplicity across agencies

2) Do you have a preference between using INDOT gradations and those specified by other agencies (e.g., AASHTO, ASTM, FAA, or state/commercial specifications)?



Listed for "Other" in Question 2.

2 Responses

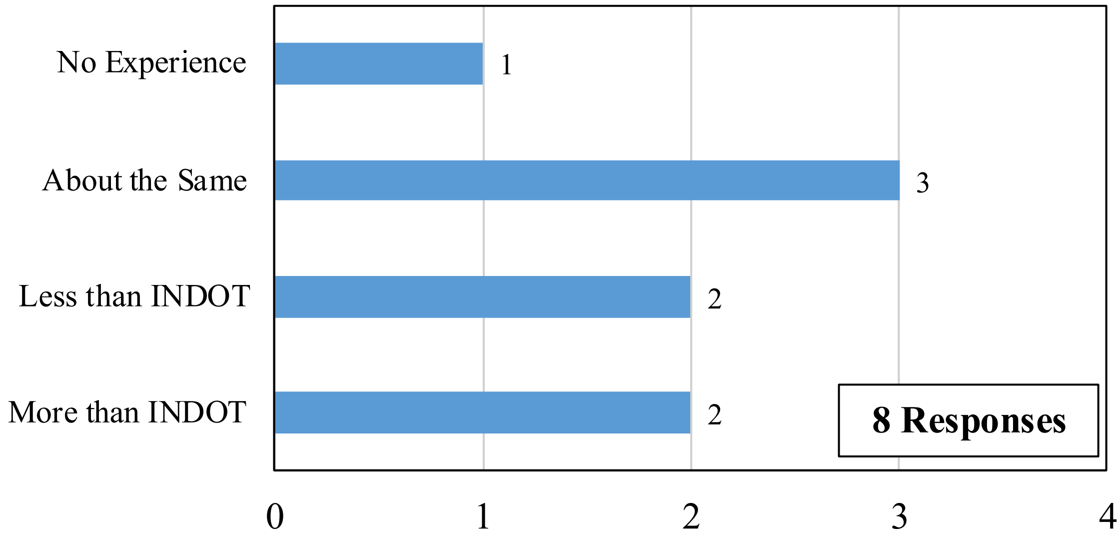
- FAA
- No preference.

2.1) Briefly explain your reasoning to Question 2.

8 Responses

- INDOT needs a concrete aggregate with more coarse material on the 3/4" sieve.
- standardizing
- The current INDOT gradations for ready mix concrete use are in the 'good' quality range. If we can figure out an agreeable time transition to optimized aggregate we will be in a good situation.
- combined gradation results
- AASHTO 5's and AASHTO 7's or 8's as an intermediate would work well for concrete paving
- The AASHTO and ASTM are basically the same and do allow the end user more flexibility in selecting materials
- Consistency is most important.
- Transportation material focused

3) **How does the amount of blending required to meet the specified final gradation compare for INDOT gradations or non-INDOT gradations (AASHTO, ASTM, etc.)?**



Non-INDOT gradations (AASHTO, ASTM, etc.) listed for "More than INDOT" in Question 3.

2 Responses

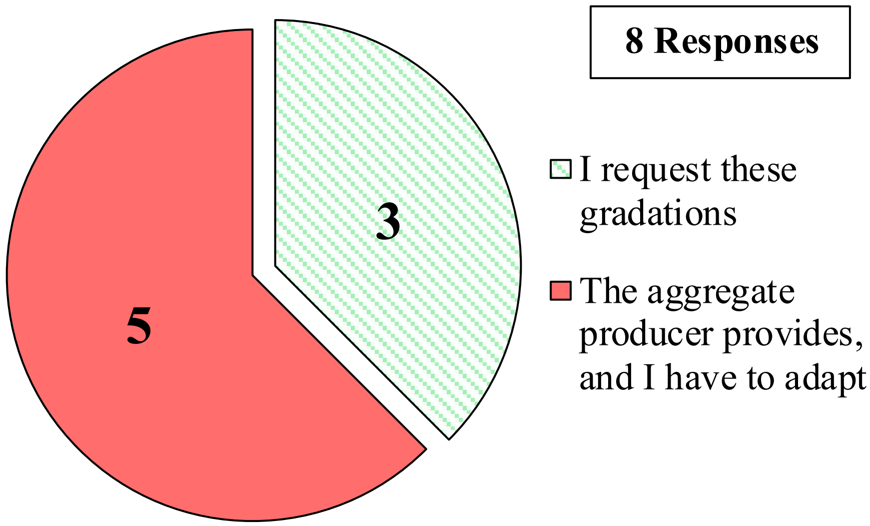
- FAA
- The ASTM and AASHTO have 1" and larger materials which currently INDOT restrict concrete to 3/4 for D cracking issues

Non-INDOT gradations (AASHTO, ASTM, etc.) listed for "Less than INDOT" in Question 3.

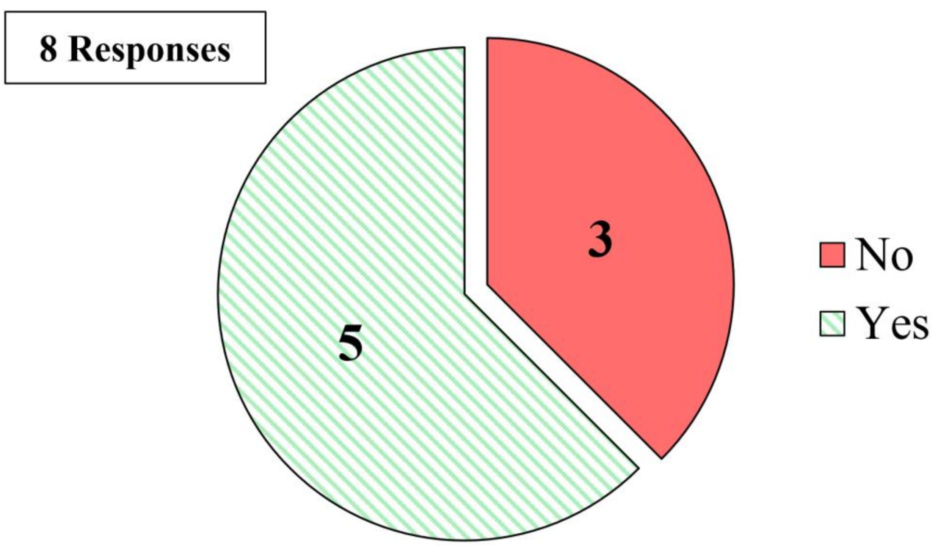
2 Responses

- ASTM
- AASHTO

4) When using QA or non-INDOT standard gradations, does this happen because you as the customer request these gradations, or does the aggregate producer provide those gradations and you have to adapt?



5) Are there any gaps or limitations in INDOT's standard gradation Table 904.03(e) that lead you to request QA (non-standard) gradations instead?



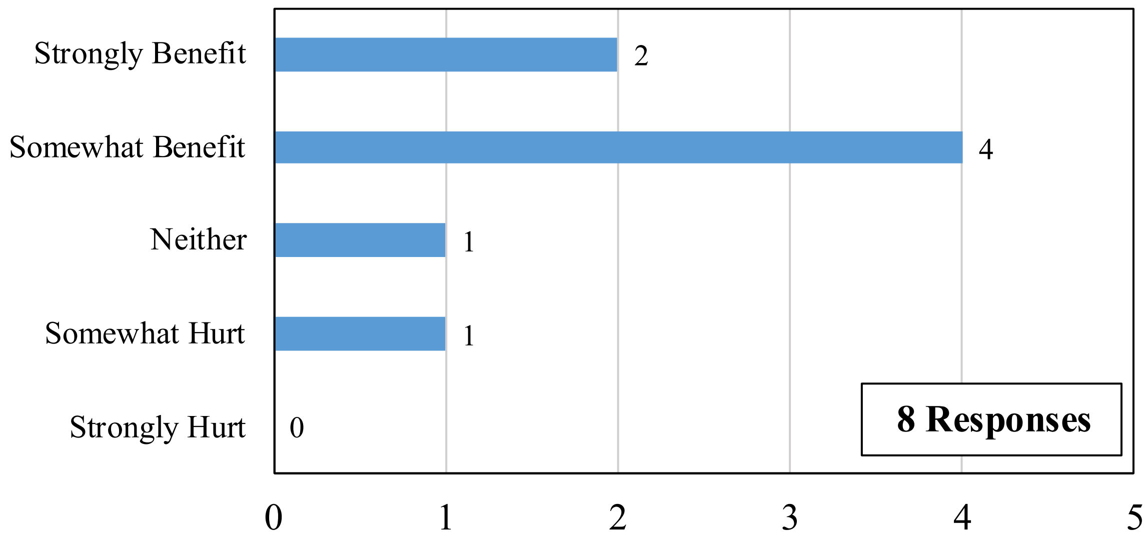
5.1) If yes, please explain.

4 Responses

- INDOTS gradations are to far from the other states making it harder for producers to produce unless they dedicate the quarry to those products
- We request to have a coarser INDOT "QA8" but seldom receive it

- Typically the minus 200 is right at the upper limit even though the CAPP documents show the production test to be very low. Also the material varies so the CAPP producer can maintain a good standard deviation
- If a local producer doesn't have a #5 then I am requesting a QA 4

6) Overall, would you benefit from or be hurt by a change from INDOT's standard gradations to AASHTO or ASTM gradations?



6.1) Please elaborate.

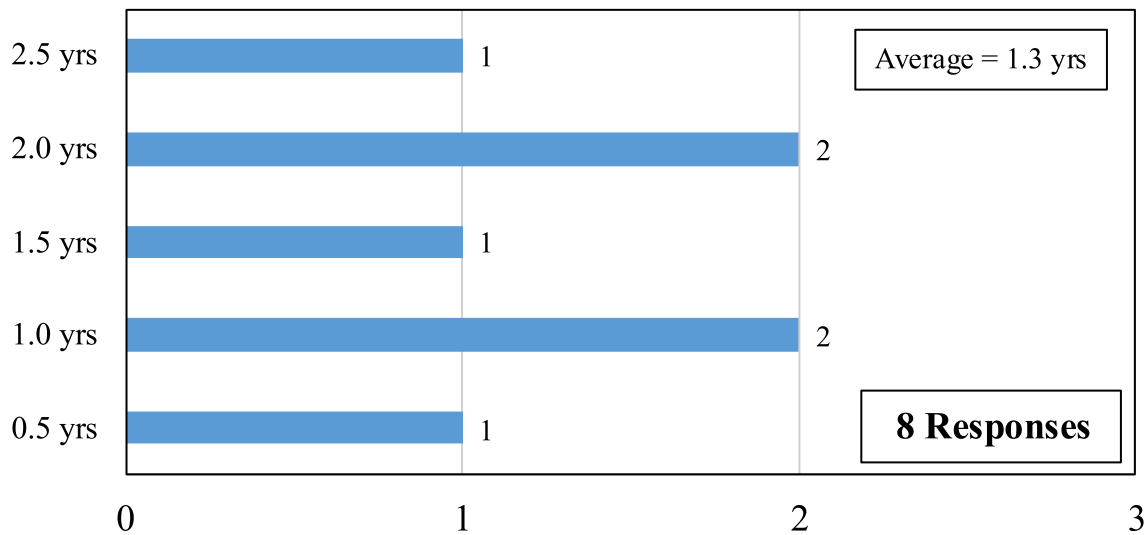
8 Responses

- Currently INDOT structural concrete contains too much paste. Better (coarser) gradations would allow for more optimized mixes that allow for paste reduction. INDOT is moving toward performance based mixes for structural concrete that will push concrete producers to use an optimized concrete mix designs. If the primary coarse aggregate is improved, less aggregate blending will be required by the concrete producer which also means that fewer bins are required.
- Making products more available.
- Some of our sources would see a reduction in quality if moving to AASHTO/ASTM. I believe we would continue to use our higher quality aggregates after the change unless it became cost prohibitave.
- I would adjust fine, i have worked in enough areas to already be prepared for either
- Ultimately we are at the mercy of the quarries but uniformity between the FAA and INDOT would be nice. INDOT 8 gradation proves difficult to keep uniform and often segregates.

However AASHTO has similar products with even fewer parameters, switching alone won't solve this issue.

- It would allow the concrete industry to open some of the material gradations up and provide moe felxibility
- consistency across state lines for customers.
- Simplicity

7) What would be an ideal transition time period if AASHTO gradations was adopted?



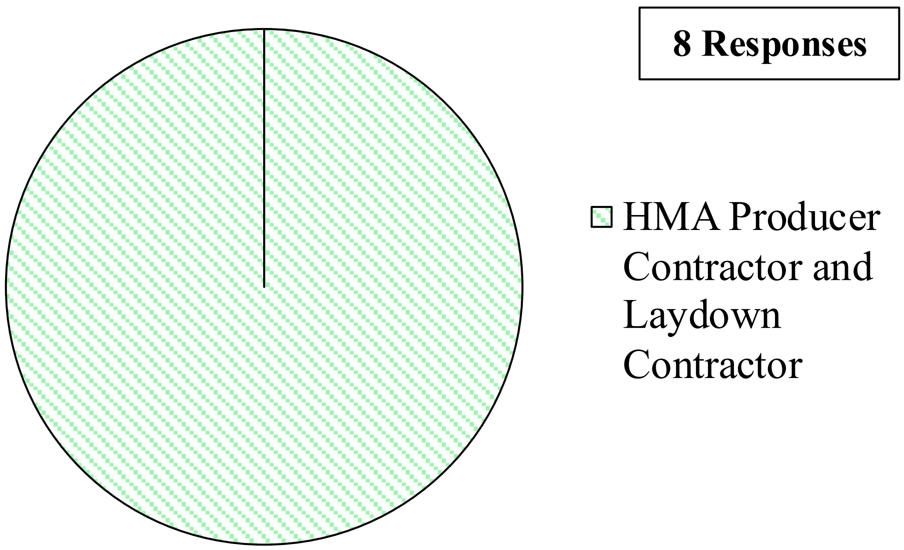
8) Please feel free to provide any other feedback, comments, or suggestions.

1 Responses

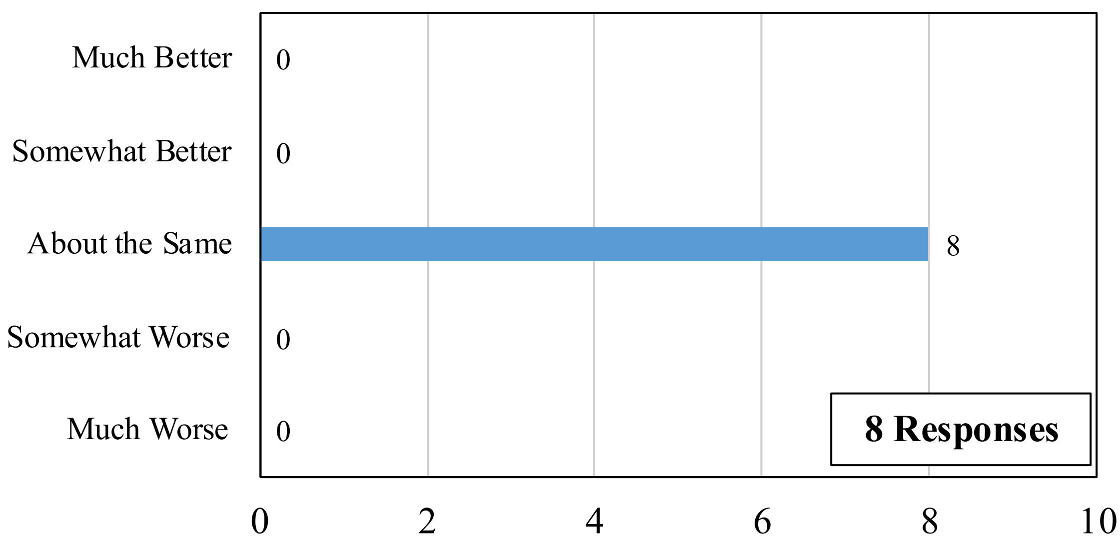
- This is all dependent on the CAPP program and the aggregate producers agreeing to the changes which is highly unlikely

Appendix F. HMA Industry Stakeholders Survey Responses

Please select the category that best describes your primary line of business:



1) **DOTs in states like Ohio and Kentucky use AASHTO or ASTM gradations, while Michigan and Illinois follow their own state-specific standards. Other specifiers, such as the FAA or commercial clients, may also require unique gradations. In your opinion, how do these alternative gradations compare to INDOT's standard gradations for concrete production or base/backfill applications?**



1.1) Please elaborate on potential drawbacks of switching from INDOT's standard gradation to these alternative gradations.

8 Responses

- Our preference is that the coarse aggregates are coarse, and we can then control the combined aggregate blend in our cold feed system. We like that our current 4 LS is a QA product and most suppliers give us a large amount of 1" and 3/4" aggregate. We would be failing AASHTO size 5 limits, which would make the aggregate forced to be finer, which would make us increase the percentage of 4LS in our mixes. Doing this gives us less control and makes our end mix have less of a well-graded gradation because we cannot control or influence the coarse side of our blends.
- Same thing applies to 9LS and 11 LS. We like to use the top sized aggregates to set the coarseness of the end product, and then combine them with smaller aggregates that fill the voids between the spaces.
- The INDOT 8LS is a double edged sword. I like the AASHTO 1/2" and lower sieves because it will influence suppliers to give a coarser product. At times we struggle with our 8 LS being too fine which causes our 3/4" sieve on our 19mm to be high 90's. However, the 90-100 tolerance on the 3/4" of AASHTO is more problematic because there is less 3/4 allowed in the aggregate blend, which will end up loading more material onto the 1/2 and 3/8 sieve.
- As we go on the finer side of aggregates, AASHTO seems to have more relaxation in the sieves. Looking at the INDOT 12LS, AASHTO 9 would again let us be a little coarser in the middle section. On intermediate and base mixtures, this will separate the AASHTO 9 to have a larger influence on the coarse aggregate side of users of the Bailey Method. Right now it is more of an awkward split from having roughly 60" passing the Primary Control Sieve, which means the INDOT 12 will be a fine aggregate, but in reality the aggregate plays 40% of the roll of influencing the coarse aggregate at the same time. On a surface mixture (9.5mm) the AASHTO 9 will be pretty much all coarse aggregate, allowing us to play more with how compatibility works on the coarser sieves. Right now The INDOT 12 is used in our surface mixtures, but we have little influence on the coarse side of a fine graded mix because we have to load so much % volume of INDOT 11 LS into our mix to give it some 3/8 and #4. Most of the time we control our properties in the fine aggregate or changing PCS from taking sand out and putting into the 12 LS. I think the AASHTO 9 would produce larger gradation changes of our mixes PCS on a smaller change of Chosen Unit Weight, which might give us more control.
- Sands we normally don't have much of an issue with, but AASHTO is more open. For us, as long as a supplier is consistent, we will control the aggregate blend in the plant. The coarse aggregates are our biggest side that we would like to see potential changes on. After that

variation from source to source is to be expected and will be handled more with a JMF change on the HMA producer side. In the HMA Industry, many aggregates are “QA”, so this is irrelevant in most cases. KYTC has a similar method by just designating NSG agg (No Specific Grade). I think this question is more of a concern to the concrete industry. It would likely require new HMA mix designs, depending on the individual agg gradation change.

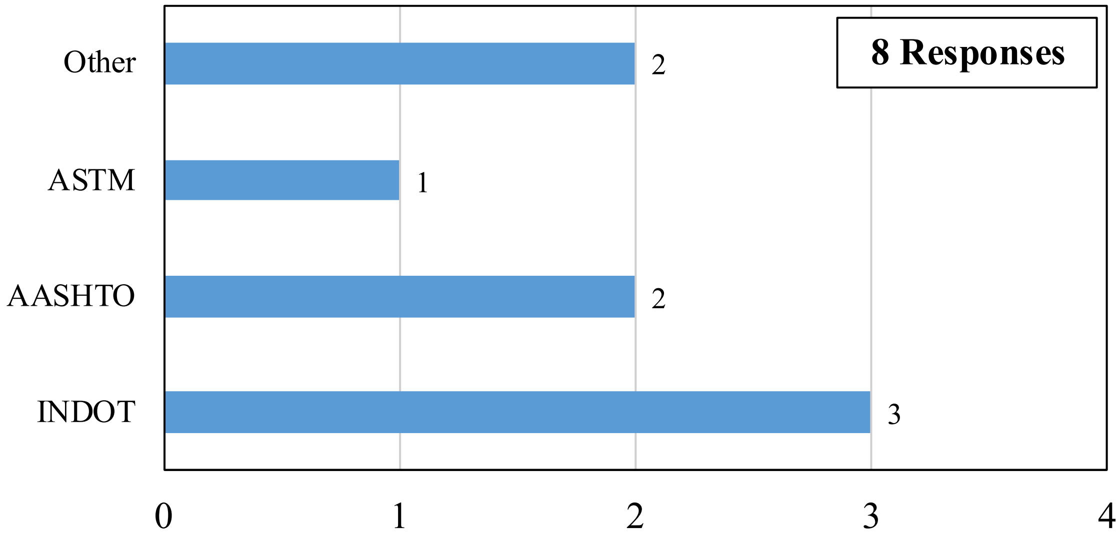
- In the HMA Industry, many aggregates are “QA”, so this is irrelevant in most cases. KYTC has a similar method by just designating NSG agg (No Specific Grade). I think this question is more of a concern to the concrete industry.
- It would likely require new HMA mix designs, depending on the individual agg gradation change.
- If a new gradation requires a greater amount of waste and/or a reduced production rate by the agg producer, supply and cost will likely be impacted.
- Changing the gradation of a given product from an agg producer typically impacts the gradation of the other products they're trying to produce at the same time. That can also impact supply and cost.
- Depending on the actual change for each product vs. where we are now, it could impact the overall combined blend gradation of mixes (for the better or worse) and thus performance (from an aggregate blend contribution point of view). That in turn might require revised gradation bands for a given asphalt mix NMAS.
- A major unknown is how the new agg gradations would blend together. As an example, contractors know how they typically blend 8's, 11's, 12's, stone sand, natural sand and RAP to develop a 19.0mm NMAS mix, including the typical amount needed of each product in a mix design. New gradations will require a learning curve on how to blend the various products to achieve an acceptable combined blend gradation. How will that impact mix cost?
- How will that impact agg availability?
- The drawback would be getting comfortable with the new gradations.
- None
- No drawback for HMA producers as most materials are made as a QA material under CAPP, but naturally, it would cause confusion for local government entities.
- Obviously creates an initial headache of full HMA redesigns. This is not a huge concern though. Just time consuming.
- No drawbacks in switching.

1.2) Please elaborate on potential benefits of switching from INDOT's standard gradation to these alternative gradations.

8 Responses

- See above
- Less confusion for contractors who do work for multiple states.
- I compared INDOT 2''s to 3's, INDOT 5's to 57's, INDOT 8's to 67's, INDOT 11's to 8's, INDOT 12's to 89's, and INDOT SC-16's to 8's.
- For the most part, the AASHTO grad's require a finer gradation on the sieve just below the Maximum. That would result in a given combined agg blend in a HMA mix having less retained on the same sieve, which is a good thing for VMA.
- However, 89's compared to INDOT 12's are considerably coarser on the #4, which would not help our current mixes that use 12's, from a VMA perspective.
- The AASHTO spec spread on the main sieves for a given product are very similar to their comparable INDOT product.
- For out of state contractors seeking to do work within Indiana, they'll likely be more familiar with the AASHTO gradations.
- The benefits would be that only one gradation would ever be necessary to produce for an aggregate supplier.
- None
- It would standardize the nomenclature between states.
- Having gradations that match neighboring states such as Kentucky and Ohio would help simplify things for producers near those borders.
- There would be a benefit. If producing aggregate gradations that were the same for multiple states it would simplify the process due to the same targets being pursued.

2) Do you have a preference between using INDOT gradations and those specified by other agencies (e.g., AASHTO, ASTM, FAA, or state/commercial specifications)?



Listed for "Other" in Question 2.

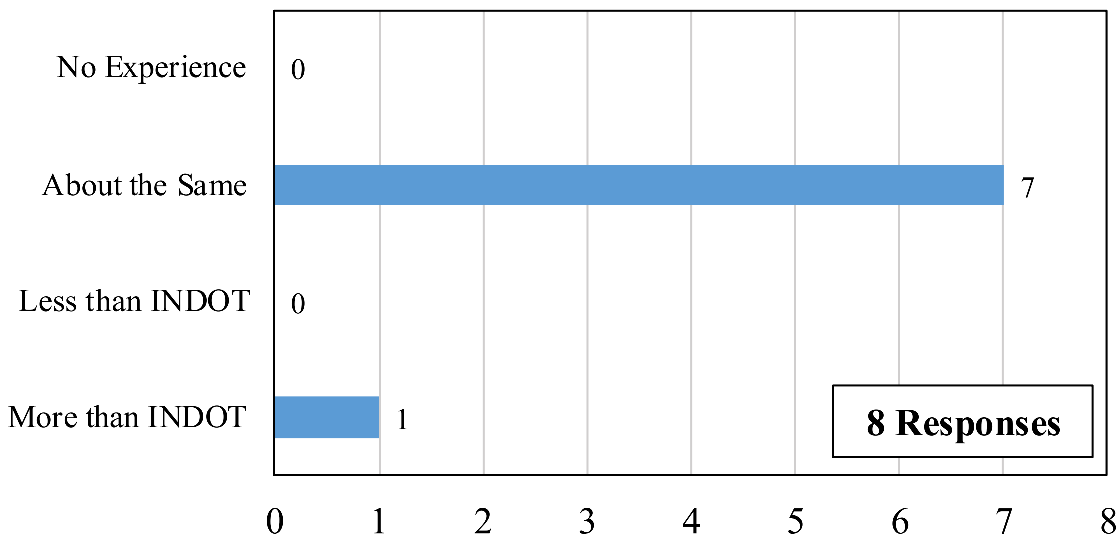
2.1) Briefly explain your reasoning to Question 2.

8 Responses

- I mostly side with INDOT due to the ability to get coarser Coarse Aggregates. I like the openness of AASHTO on a fine aggregate, but again I don't think we struggle with that now. I did look at Illinois briefly, they seem to have more products, which would be more difficult to switch to in order to make sure you are calling everything correctly. Michigan also seems to be more in the middle.
- If we are to standardize between states, it should be AASHTO. As I said earlier, INDOT uses it's CAPP program to produce "QA" aggregates anyway, so it doesn't really matter much to me as an HMA producer.
- What we have now is working.
- As opposed to changing the gradation bands for a given product, tightening the allowable agg production tolerances (relative to the targets established by the agg producer) would reduce gradation variability in our HMA mixes. HMA contractors can encourage their agg suppliers to reduce gradation variability, but reality is HMA producers have little to no control over this and are often forced to figure out how to make it work at the HMA plant.
- Years and years of data using INDOT specs.
- Either are fine

- I work with both INDOT specs and KY (AASHTO), but it would simplify things for the HMA industry to be working with one standard between states
- Helps to standardize operations.
- ASTM gradations being utilized in many commercial/FAA/COE specifications.

3) How does the amount of blending required to meet the specified final gradation compare for INDOT gradations or non-INDOT gradations (AASHTO, ASTM, etc.)?



Non-INDOT gradations (AASHTO, ASTM, etc.) listed for "More than INDOT" in Question 3.

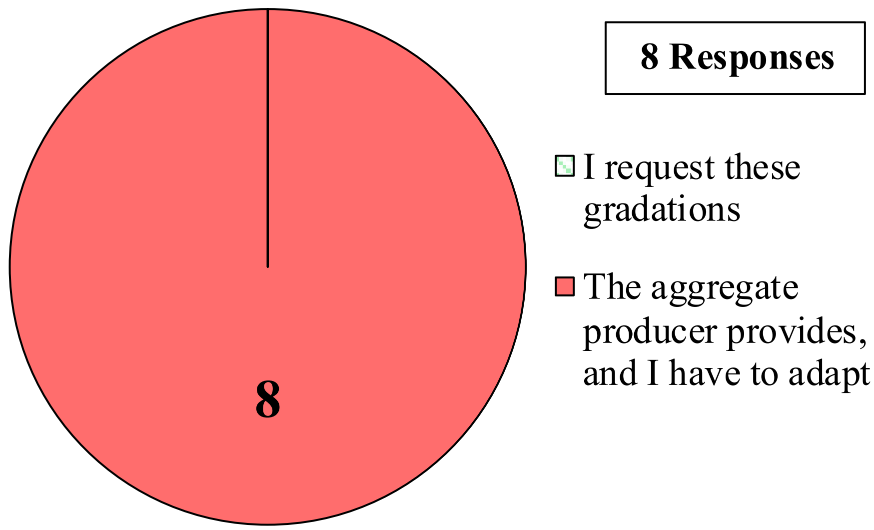
1 Responses

- I chose this simply to reinforce an earlier comment that we won't know how the new (AASHTO) gradations would impact blending until it actually happens. We generally combine agg products from multiple agg producers. The new grad bands might impact one agg producers product more than another, which could have a positive or negative effect when combining those products for an individual HMA mix.

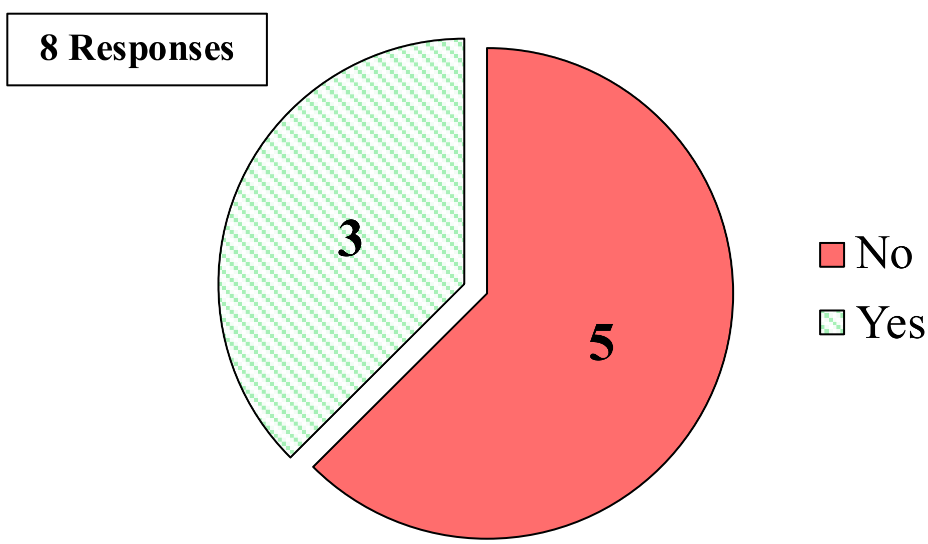
Non-INDOT gradations (AASHTO, ASTM, etc.) listed for "Less than INDOT" in Question 3.

0 Responses

4) **When using QA or non-INDOT standard gradations, does this happen because you as the customer request these gradations, or does the aggregate producer provide those gradations and you have to adapt?**



5) **Are there any gaps or limitations in INDOT's standard gradation Table 904.03(e) that lead you to request QA (non-standard) gradations instead?**

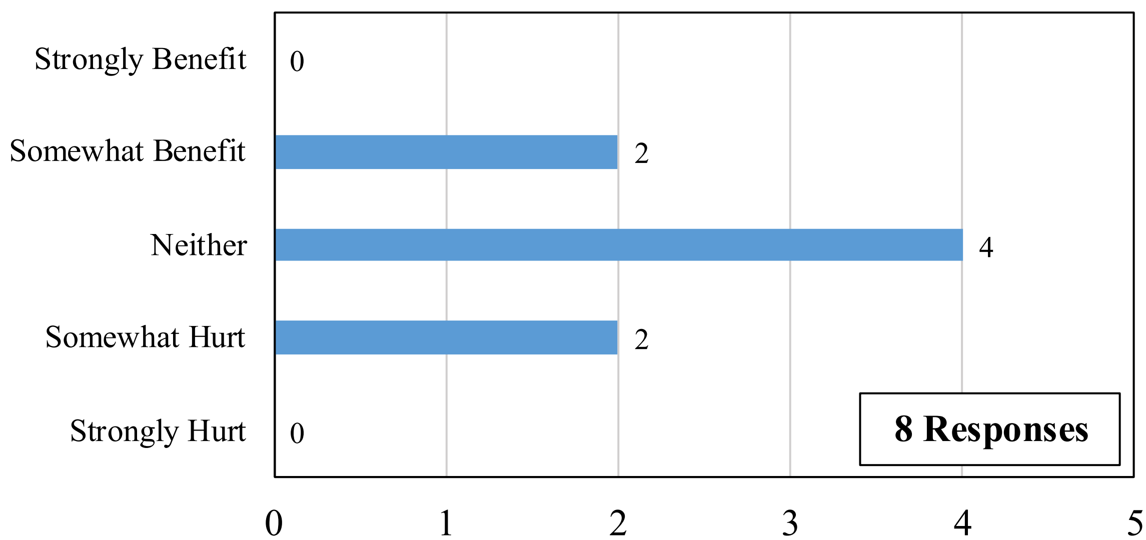


5.1) If yes, please explain.

4 Responses

- Most of the time we use the product that the supplier has. If its QA that's fine with us. Normally they are doing that because they are stripping 12 LS out of the coarse products so they can sell to other customers. That isn't a problem to us because we can just add the 12 LS back into the mix. The key is just to give us consistency. Obviously it would be a huge concern if a supplier did this without us knowing
- I find this is more of an issue with fine aggregates, but as an HMA producer, I have personally requested that Coarse aggregates be more single size rather than long graded INDOT gradations. That gives us more control and flexibility at the asphalt plant as We do the blending
- QA is already what most producers make. Not sure how changing the spec to AASHTO will affect the agg producers, but as for HMA producers, the QA spec is mostly used. I believe having a separate INDOT spec causes the aggregate producers to make both, since some local governments specify INDOT gradations. I see this as more of a problem for agg suppliers than HMA producers.
- Intermediate clean fine aggregate (QA#14) to enhance HMA volumetrics.

6) Overall, would you benefit from or be hurt by a change from INDOT's standard gradations to AASHTO or ASTM gradations?

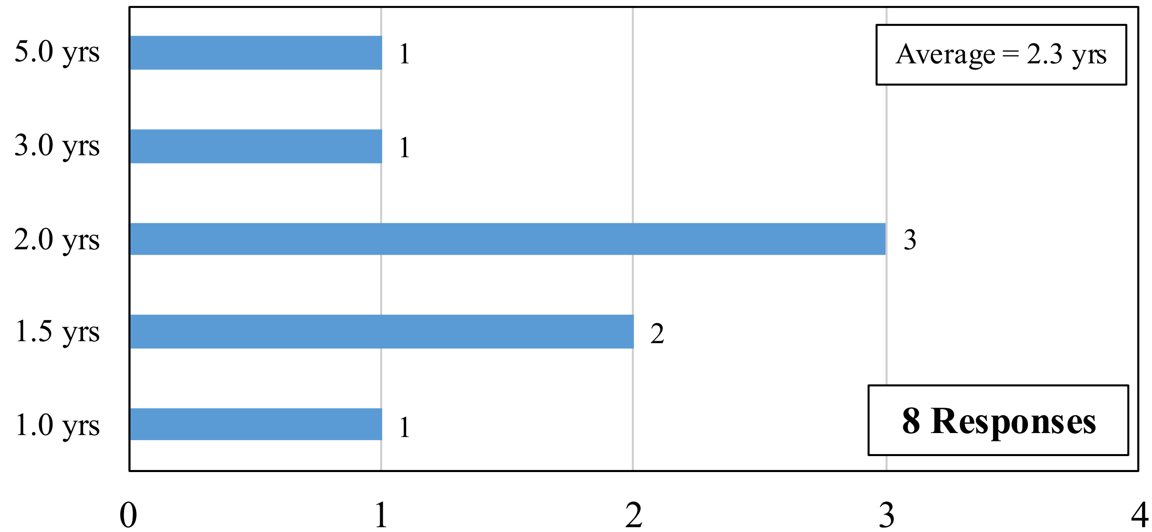


6.1) Please elaborate.

8 Responses

- A change to new aggregates would force a redesign of all of our products. I would expect aggregate quarries to have variability at the beginning as they figure our how to best manage their plants to produce the highest yield. Also the finer products would be more of a headache on plant operators if I have to start putting very high percentages of one sized aggregate in. For example, if a 19.0mm mixture required a very high amount of AASHTO 6, I would require the plant operator to split the aggregate % into two cold feeds so the plant could manage that load.
- I don't think it will really affect us in the HMA industry. AS I said, if I could change anything at the quarries, I would go for single sized aggregates if it can remain our choice. Our CAPP “QA” aggregates allows for this. Going to AASHTO though, would simplify communications between agg producers and Contractors who supply both states.
- There are a lot of unknowns, especially when we combine products from multiple agg producers. We have a lot of historical knowledge and experience to draw from today. Not knowing how the changes would impact supply, cost, our ability to blend products, etc., is concerning. The potential negatives appear to outweigh the benefits.
- Until I try using the new aggregate gradations, , I won’t know the effect on blend.
- Ham is blended to new grading targets with multiple products
- As explained earlier, we use the CAPP “QA” materials. I would hope this stays in place, as it gives us more options than if an aggregate used in HMA had to meet either INDOT or AASHTO standard gradation.
- We would adapt as necessary.
- Uniformity of specifications across state lines and also for FAA/COE/commercial projects.

7) **What would be an ideal transition time period if AASHTO gradations was adopted?**



8) **Please feel free to provide any other feedback, comments, or suggestions.**

1 Responses

- N/A

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at docs.lib.purdue.edu/jtrp/.

Further information about JTRP and its current research program is available at engineering.purdue.edu/JTRP.

About This Report

An open access version of this publication is available online. See the URL in the citation below.

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