Triangle Tech Tips
References and resources from Triangle Ready Mix
Publication # 25-03-093

The Impact of Graded Aggregates on Concrete Performance

The term "graded aggregates" refers to a mixture of different-sized particles of coarse and fine aggregates that are proportioned to achieve a dense, compact, and well-distributed particle arrangement in concrete. The grading of aggregates significantly affects the workability, strength, durability, and overall performance of the concrete mix. Types of graded aggregates include:

- **Well-Graded Aggregates:** Contain a balanced mix of different-sized particles that minimize voids and enhance concrete density and strength.
- **Gap-Graded Aggregates:** Lack certain intermediate sizes, resulting in more voids and a rougher texture, sometimes used for specific applications like exposed aggregate concrete.
- **Uniformly Graded Aggregates:** Consist mainly of particles of the same size, leading to high void content and increased cement paste demand.
- **Open-Graded Aggregates:** Have minimal fine particles, making them more permeable. Open-graded aggregates are commonly used in drainage applications.

Well-graded aggregates contain a balanced distribution of particle sizes, ranging from coarse to fine, to minimize voids and maximize density in a concrete mix. This type of aggregate distribution ensures efficient particle packing, reducing the need for excess cement paste and improving the overall performance of the concrete.

How do well-graded aggregates benefit concrete?

1. Improved Workability: A well-graded aggregate mix ensures better particle packing, reducing the amount of voids in the mix. This leads to smoother placement, easier finishing, and less segregation.

2. Increased Strength: Properly graded aggregates create a denser concrete matrix, which enhances compressive strength and durability by reducing weak points and minimizing excess water demand.

3. Reduced Shrinkage & Cracking: With fewer voids to be filled with cement paste, the concrete requires less water, leading to lower shrinkage and reduced risk of cracking over time.

4. Better Durability: Dense and well-compacted concrete with graded aggregates is more resistant to environmental factors such as freeze-thaw cycles, abrasion, and chemical exposure.

5. Optimized Cement Use: A well-graded aggregate mix minimizes excess paste requirements, reducing the amount of cement needed, which improves cost efficiency and lowers the concrete's carbon footprint.

6. Enhanced Pumpability: Graded aggregates improve concrete flow and cohesion, making it easier to pump over long distances without segregation or blockages.

What studies have been done on graded aggregates in concrete?

A 2016 study titled *"Gradation of Aggregates and its Effects on Properties of Concrete"* compared well-graded, uniformly graded, and gap-graded aggregates in typical concrete mixes. The findings revealed that well-graded aggregates exhibited superior compressive strength and workability compared to gap-graded aggregates.

Similarly, research published in the *International Research Journal of Engineering and Technology* in 2019 examined the optimization of aggregate gradation and its effects on concrete properties. The study concluded that well-graded aggregates contribute to improved concrete performance, including enhanced strength and durability.

Creating a superior graded aggregate mix results in stronger concrete.

Most ready-mixed concrete producers today still use traditional repose batching for blending concrete. This method has not changed significantly in almost a century. Triangle Ready Mix utilizes a different method, called precision inline aggregate blending.

Inline aggregate blending produces a more consistent and superior well-graded aggregate blend compared to traditional repose batching. Inline aggregate blending offers more precise, consistent, and efficient results for producing well-graded aggregates, making it superior to repose batching for most standard concrete mixes.

In addition to producing concrete of superior strength, inline aggregate blending offers theses advantages:

1. **Better Control:** More precise control over the gradation, resulting in a well-graded aggregate blend with fewer variations.
2. **Higher Consistency:** Since the process is automated, it reduces human error and inconsistency in the mix, ensuring uniformity from batch to batch.
3. **Efficiency:** The mix is uniform and optimized for strength, durability, and workability, all while minimizing voids and cement paste demand.
4. **Faster Production**: Inline blending allows for quicker adjustments and continuous mixing, improving efficiency and reducing batch times.

Conclusion

In conclusion, graded aggregates play a critical role in enhancing the overall performance of concrete, from improving workability and strength to reducing shrinkage and boosting durability. Well-graded aggregates, in particular, offer significant advantages by minimizing voids, optimizing cement use, and ensuring a dense, compact concrete matrix. Research consistently supports the benefits of well-graded aggregates in creating superior concrete mixes.

As traditional batching methods give way to more advanced techniques, inline aggregate blending stands out as a more efficient and precise method for producing consistent, high-quality mixes. By leveraging this innovative approach, companies like Triangle Ready Mix ensure the production of concrete that is not only stronger but also more sustainable and cost-effective. This commitment to quality and innovation helps meet the demands of modern construction, contributing to durable and high-performance structures.

Figure 1: Results of a 2017 field test, showing strength advantage of inline aggregate blending

In 2017, a ready mixed concrete producer in Kansas experimented with reduced cement content to test the quality of the inline blending process. Using 470 lbs/yd^3 of cement instead of the standard 564 lbs (a reduction of 16.7%) for a 3-1/4 inch slump mix, compression testing showed strength of the concrete still exceeded the 4,000 psi specification by 1,460 psi at 28 days, thus showing that precision inline aggregate blending produces concrete of superior strength.

Cement Holcim	**470** lbs/cy		sk	Slump	**3 1/4** in.
Fine Aggregate	**1989** lbs/cy		%	Unit Wt.	lbs/cf
Course Agg	**1286** lbs/cy		%	Yield	lbs/cy
Water	**212** lbs/cy		gal/cy	Air	**4.5** %
Fly Ash	lbs/cy		sk	Conc. Temp	**56** °F
Admixture Type	**Daravair 1000**	**AEA**	**2** oz/cy	Air Temp.	**58** °F
Admixture Type	**Mira 95**	**Water Reducer**	**38** oz/cy	Time	**11:15** AM
Strength Required	**4000** psi @		**28** days;	psi @	days

LAB NO.	C170407.084		C170407.085		C170407.086	
DATE / TIME TESTED	4/14/17	8:45 AM	4/21/17	8:00 AM	5/5/17	8:10 AM
AGE IN DAYS WHEN TESTED	7		14		28	
DIAMETER (INCHES)	3.98		3.98		3.97	
CROSS-SECTIONAL AREA (IN^2)	12.44		12.44		12.38	
MAXIMUM LOAD	54080		56940		67600	
COMPRESSIVE STRENGTH PSI	4350		4580		5460	
TYPE OF FRACTURE	Type 3		Type 5		Type 3	
WEIGHT (LBS)	8.411		8.416		8.349	
LENGTH (IN)	8		8		8	