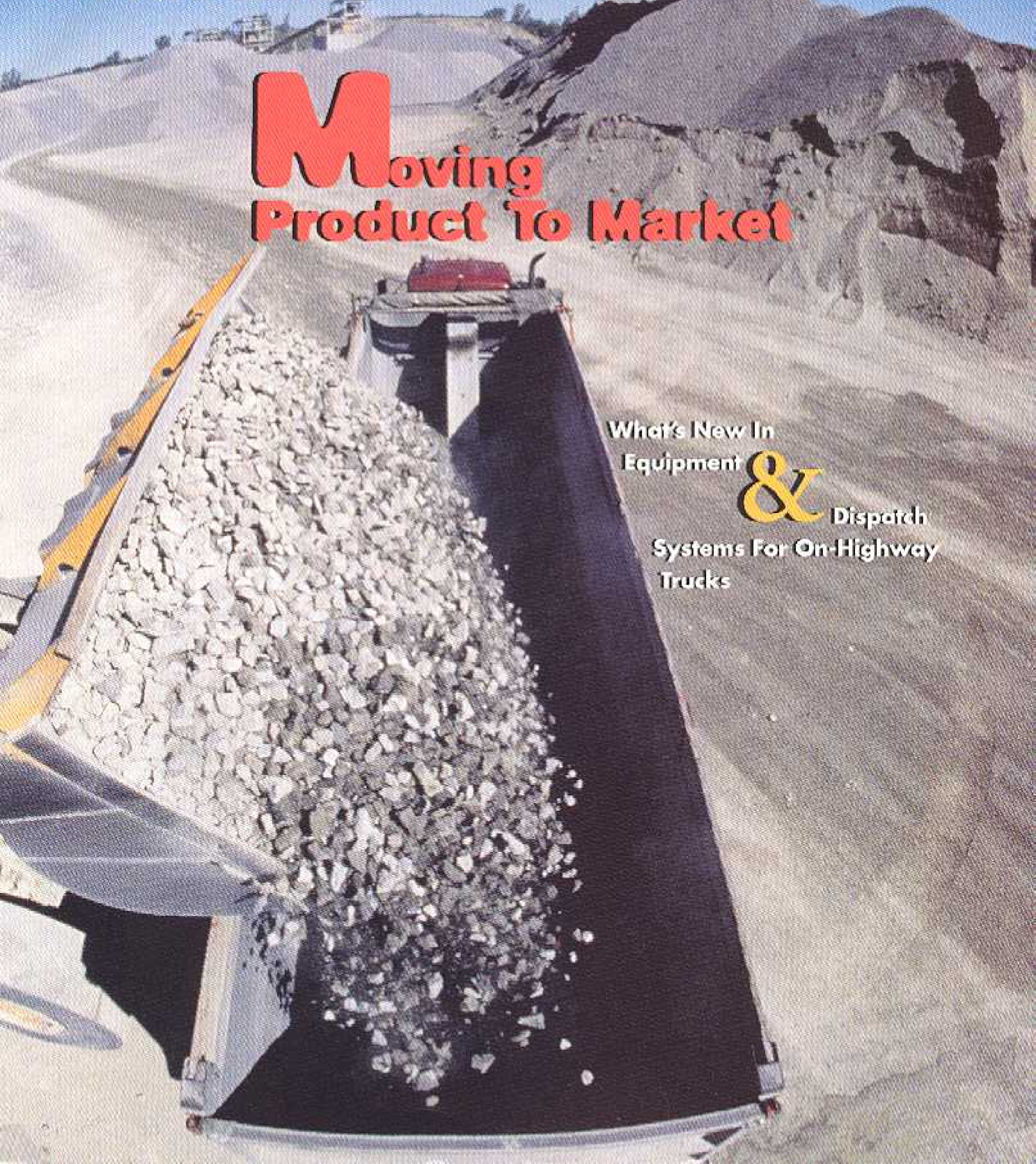
ROCK PRODUCTS®

AN INTERTEC®/K-III PUBLICATION

JULY 1997



Moving Product To Market

What's New In Equipment & Dispatch Systems For On-Highway Trucks contents

An INTERTEC® Publication

ROCK PRODUCTS®

DEPARTMENTS

ON THE COVER

Transporting aggregate from mine to market.
Photo courtesy of France Stone, a subsidiary of Cornerstone Construction & Materials

NEXT MONTH

Crushed stone operations; plus, hydaulic breakers.

FEATURES

26

32

EQUIPMENT FOCUS

52

CLSM consistency is measured using a flow test: fill a 3- x 6-in. open-end cylinder on a level surface (top or left) and then raise the cylinder to allow the material to flow out. Specifications require that the resulting patty have at least an 8-in. diameter and no visible segregation (bottom or right).

High-fines limestone screenings prove viable as aggregate for excavatable Controlled Low-Strength Material

by L.K. Crouch and Rod Gamble

An International Center for Aggregates Research (ICAR) survey indicated that the greatest challenge facing aggregate producers deals with by-product fines, often referred to as screenings. Industry leaders estimate that more than 200 million tons of screenings were generated in 1993.

It is difficult to find viable uses for by-product fines, which account for 15% to 25% of aggregate production. Most construction- and highway-material specifications limit the amount of material finer than 0.075 mm (minus 200 mesh) to 6% or less. The combination of large supply and small market has resulted in millions of tons of screenings accumulating in stockpiles.

ICAR identified Controlled Low-Strength Material (CLSM), commonly called flowable fill, as a promising use for large volumes of by-product fines. The estimated U.S. market for CLSM of all types is approximately 10 million cu yd in 1997.

If proved viable as flowable-fill aggregate, high-fines limestone screenings would provide significant benefits:

- decreased storage and disposal costs;
- watershed protection;
- more efficient use of a dwindling natural resource;
- increased revenue for aggregate producers; and
- decreased material costs for ready-mixed concrete producers and end-users of flowable fill.

Reviewing recommendations for excavatable CLSM mixes from industry and government organizations, it appears that National Ready Mixed Concrete Association (NRMCA) recommendations are ideal. NRMCA recommends that excavatable CLSM mixes should have a compressive strength of more than 20 psi at three days, more than 30 psi at 28 days, and ultimate compressive strength of less than 150 psi.

Minimum strength recommendations ensure that CLSM has adequate bearing capacity and does not settle (deform) excessively under load. Maximum strength recommendations ensure that CLSM can be removed with conventional excavating equipment.

Consistency of CLSM is measured by filling a 3- x 6-in., open-end cylinder or pipe with CLSM on a level surface and then raising the cylinder to allow the ma-

Putting More Fines In Flowable Fill

terial to flow out. Most specifying agencies agree that a patty with a minimum 8-in. diameter and no visible segregation is adequate.

Prior to development of performance-enhancing admixtures, flowable-fill mixes bled off excess mix water to consolidate after placement. The presence of significant amounts of material finer than 0.075 mm in the aggregate impeded bleeding. Most specifying agencies, therefore, limited the amount of aggregate finer than 0.075 mm to less than 10%.

New performance-enhancing admixtures limit strength, prevent segregation, and enhance workability by entraining large percentages of stable air bubbles in flowable-fill mixtures. Flowable fill containing these admixtures does not bleed and therefore possibly could use aggregates containing more than 10% finer than 0.075 mm.

Flowable-fill tests

The two commercially available, flowable-fill performance-enhancing admixtures selected for the study were W.R. Grace Construction Products' Darafill and Master Builders Technologies' MB AE 90. These admixtures were selected due to their nationwide availability.

To determine if high-fines limestone screenings were a viable flowable-fill aggregate, multiple batches of flowable fill containing limestone screenings with 0%, 7%, 14%, 21%, and 28% finer than 0.075 mm were mixed. In addition, a mix containing a performance-enhancing admixture and river sand aggregate, as well as a traditional, non-air-entrained mix were made to serve as standards for economic comparison.

The plastic properties of each batch were characterized by the open-end cylinder flow test, volumetric air test (ASTM C173), and unit weight (ASTM C138). Strength development (ASTM C39) over time—three, seven, 28 and 60 days—was determined using 2- x 4-in. cylinders. Ultimate strengths were simulated by curing at elevated temperatures.

The results of each round of testing were analyzed and the mixes were adjusted in an attempt to meet NRMCA performance recommendations. Economy was found to be primarily a function of cement content, admixture dosage, and aggregate cost. Therefore, the research team concentrated on producing mix designs that met NRMCA performance recommendations with minimum cement and admixture contents.

Getting enough air

Proper air content in a well-designed CLSM mix limited strength, generated proper flow, eliminated segregation, and greatly reduced bleeding by producing a cohesive, homogeneous mixture. The proper air content is a function of many factors, but air contents of 14% to 30% worked well in this study.

If the air content is less than 14%, there is a good chance that the ultimate strength of the mix may exceed the desired level. In addition, a low air content may produce a bleeding mix with inadequate flow. If the air content exceeds 30%, it will be difficult to achieve early strength goals with cement contents less than 200 lb/cu yd.

Air content of the mixes in this study appears to be a function of five factors. These factors, in apparent order of importance, are:

1. admixture type;

Benefits Of Using CLSM

Controlled Low-Strength Material (CLSM), also called flowable fill, is a self-compacting blend of portland cement, aggregate, water, and possibly admixtures. CLSM mixtures, which when hardened can be excavated with conventional digging equipment, are an economical alternative to placing and compacting soil or granular materials for backfilling utility trenches for the following reasons:

- Reduced labor costs—it requires no compaction.
- Worker safety—fewer workers are in the trench for a shorter period.
- Reduced settlement of the overlying pavement—the fluid consistency of CLSM ensures a high-density backfill.
- Placement in confined areas at high density—access for compaction equipment is not required.
- Fail safe—if CLSM deteriorates in place, it will continue to act as a granular backfill.
- Easily removed—properly designed CLSM can be easily removed by conventional soil-excavation equipment.
- Durability—CLSM typically is less permeable and more stable than granular backfills.

2. fines content (<0.075 mm);
3. water content;
4. aggregate particle shape; and
5. admixture dosage.

Darafill entrained higher percentages of air than MB AE 90 for every gradation. The difference in percent air entrained increased from the 7%- to the 14%-fines gradation, and even more dramatically from the 14%- to the 21%-fines gradation.

In general, air content decreased as the percentage of the aggregate passing 0.075 mm increased. This effect was more pronounced for MB AE 90 than for Darafill. However, the research team was unable to entrain a significant air content in a mix containing aggregate with 28% passing 0.075 mm with either admixture.

Above a certain minimum water content, WRG Darafill entrained less air as water content increased. However, MB AE 90 entrained more air as water content increased.

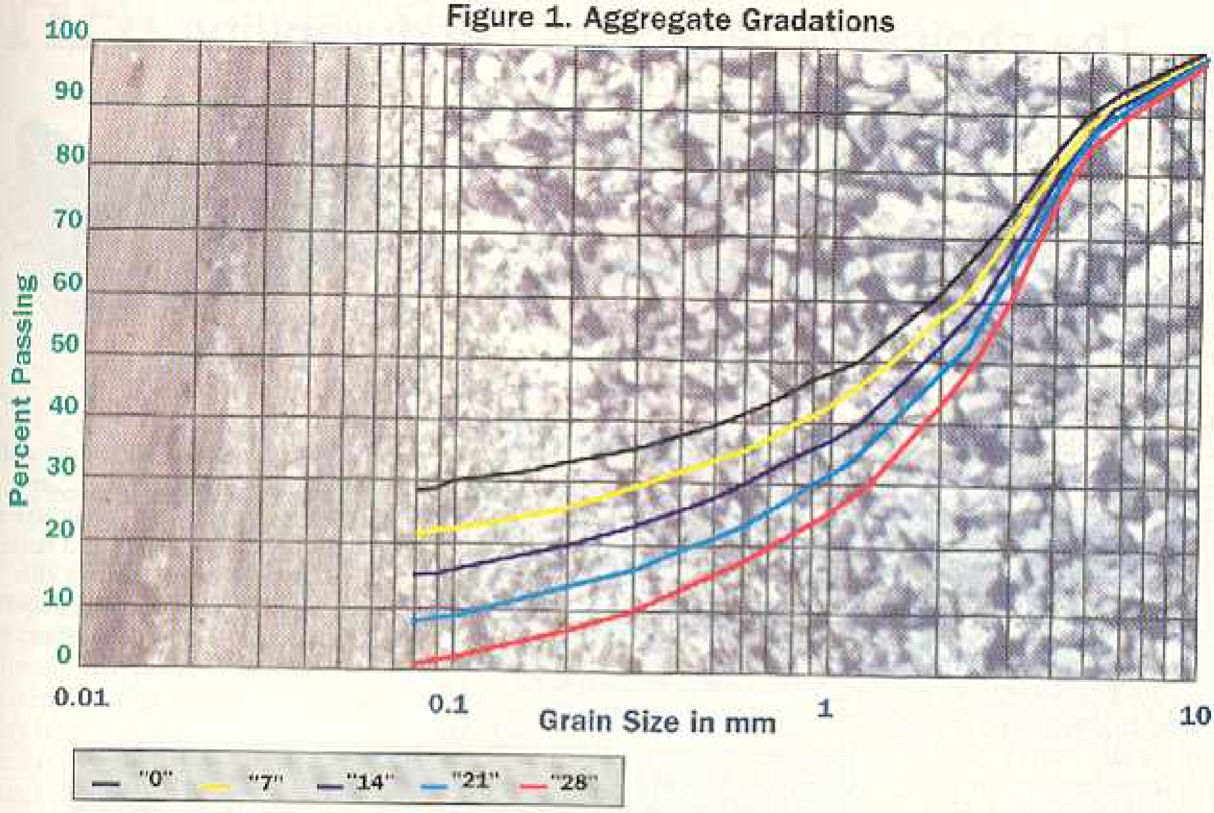
From the limited use of rounded aggregates in this project, and from discussions with admixture manufacturers, it was determined that angular (crushed) aggregates entrain significantly higher air contents than rounded aggregates for similar mixes. This increase in air content partially offsets the reduction in air content due to increasing the percent of the aggregate passing 0.075 mm. However, the effect of percent passing 0.075 mm rapidly supersedes the effect of angularity as the percent passing 0.075 mm increases.

The admixture dosage rate appeared to have the least effect of the five factors, provided that the dosage rate was above a certain minimum. Until more definitive research is available, the authors recommend using the manufacturers' recommendations.

Table 1: CLSM Test Mix Designs And Properties

% Fines (<0.075 mm)	0	7	14	21	0	7	14	21
Cement (lb/cu yd)	150	150	150	125	150	150	150	150
Water (Net) (lb/cu yd)	370	370	400	400	280	320	320	300[1]
Water (Abs.) (lb/cu yd)	28.33	28.55	30.98	38.12	29.03	27.99	31.42	39.18
Aggregate[2] (lb/cu yd)	2,421	2,424	2,348	2,372	2,481	2,378	2,382	2,437
Admixture (oz/cu yd)	70	70	70	70	1.5	3.0	3.0	3.0
Type Of Admixture[3]	MB	MB	MB	MB	WRG	WRG	WRG	WRG
Flow (in.)	11.375	10.25	10.25	11.00	13.00	12.00	8.25	8.25
Air Content (%)	22.0	21.0	14.5	9.5	28.0	22.5	22.5	20.5
Unit Weight (lb/cu ft)	97.0	101.9	108.8	112.5	96.5	103.7	100.6	102.3

[1]Added 13.5 lbs/cu yd water after 10-minute mix cycle to increase flow.
[2]Oven-dry aggregate
[3]MB=Master Builders' AE 90; WRG=W.R. Grace Darafill



Aggregate gradations for test CLSM mixes containing 0%, 7%, 14%, and 21% fines (<0.075 mm).

The primary factors affecting strength development of air-entrained CLSM mixes were cement, air, and water contents. If a proper air content (14% to 30%) cannot be obtained, strength can be reduced by increasing the water content and decreasing the cement content.

Similarly, proper flow should be achieved with a proper air content (14% to 30%) and a water content as low as possible to minimize segregation and bleeding. Flow also may be increased by increasing the cement content. However, all engineering properties of the mixture are interrelated, so alteration of one property almost always has collateral effects.

In summary, these mixes (Table 1) are meant as a good starting point for producers or testing laboratories to design mixes for specific applications using locally available materials. They are not intended as universal recipes for properly performing excavatable CLSM.

Conclusions

1. Limestone screenings containing as much as 21% finer than 0.075 mm can be used as aggregate to produce a flowable fill mix meeting NRMCA performance recommendations.
2. Proper air content in a well-designed mix limited strength, generated adequate flow, eliminated segregation, and greatly reduced bleeding by producing a cohesive homogeneous mixture. Proper air content for flowable-fill mixes containing limestone screenings as aggregate appears to be 14% to 30%.
3. Flowable-fill mixes containing limestone screenings containing as much as 21% finer than 0.075 mm can be economically attractive in markets where other aggregates are expensive. In markets where river sand is expensive or difficult to obtain, flowable-fill mixes containing limestone screenings are competitive in price.

L.K. Crouch is associate professor of civil engineering, Tennessee Technological University; and **Rod Gamble** is area manager, Rogers Group. This paper was presented at ICAR's Fifth Annual Aggregates Symposium in Austin, Texas, and is reprinted with permission.

Acknowledgements

The authors gratefully acknowledge the support of the Rogers Group Inc. W. R. Grace Construction Products and Master Builders Technologies donated materials and provided advice. The following individuals provided technical assistance:

- Williams E. Brewer, ACI Committee 229;
- R. Wayne McCamey and Larry Clouse, Master Builders Technologies;
- Doug Poe and Ken Nelson, W. R. Grace Construction Products;
- James F. Brogdon and Charles J. Tucker, graduate teaching assistants, Tennessee Technological University (TTU);
- Barry N. Whitten, Jason Burgess, and Jason Laxson, undergraduate research assistants, TTU; and
- Richard Maxwell, technician, TTU