ENHANCING PERFORMANCE OF SOUNDLESS CHEMICAL DEMOLITION AGENTS

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ABSTRACT: Soundless chemical demolition agents (SCDAs) have been used in a variety of circumstances where other more conventional means of demolition were not feasible. When compared with conventional explosives, SCDAs are not yet economically competitive. Research was conducted on SCDAs to examine the possibility of adding an inert material (sand) to the SCDA in order to extend the material. Results show that although the expansive pressure generated by the SCDA is reduced by adding sand, reduction is not commensurate with the amount of sand added. Research was also conducted in order to determine if the workability of the SCDA slurry could be improved by adding a superplasticizer. These tests were conducted at water contents below levels where conventional mixtures were too stiff to effectively deposit them in a borehole. Results show that a superplasticizer can effectively improve SCDA workability and that the resultant expansive pressure is greater than that which is possible without the superplasticizer.

INTRODUCTION

Soundless chemical demolition agents (SCDAs) have many useful purposes. They can be used either to reduce large boulders to more manageable sizes or to demolish rock and concrete structures. They can also be used in areas where explosives are prohibited, near environmentally sensitive areas, under water, and so on. SCDAs have been used in a wide range of applications, and additional uses will emerge as more firms begin to recognize the value of these products.

Despite their versatility, SCDA performance is subject to compromise in certain instances. The hydration process in particular, which is very sensitive to changes in water content, can produce significantly different results if, for example, extra water is added in order to enhance workability. While it may not be possible to fully control or eliminate all of the limitations to SCDA performance, some steps can be taken to reduce their effects and make SCDAs more suitable for more applications.

One drawback of SCDAs is cost. When compared to common explosives, such as dynamite and ammonium nitrate, SCDAs are often more expensive. SCDAs compete successfully with conventional explosives when demolition projects take place near other structures, gas lines, or populated areas along shipping channels and in areas where explosions, noise, shock vibrations, toxic fumes, and the like are not acceptable.

Other drawbacks associated with SCDAs are workability and ease of placement. While some water can be added in order to enhance workability, additional water reduces maximum pressures ultimately generated. The relationship between water content and SCDA performance was examined in a prior study at the University of Washington (Hinze and Brown 1994). That study showed how expansive pressures were highest when the water/SCDA ratio was at the lowest recommended value of 30%. Although a slurry containing 30% water was achievable, the material was very stiff and not very workable. Thus, the practical lower limit for additional water appeared to be at, or slightly above, 30%.

This prior research also showed that SCDA performance is quite sensitive to variations in temperature. Experiments conducted at various temperatures demonstrated that expansive pressures reached higher values at higher temperatures. This was true even when experimental temperatures were well above the SCDA manufacturer's maximum suggested temperature ranges.

It has been noted that the heat of hydration of SCDAs can be substantial, perhaps as high as 150°C. If free water is trapped in the SCDA mixture, such temperatures may pose a problem by producing superheated steam. This in turn can potentially result in the SCDA being ejected from the borehole, threatening worker safety and obviously compromising SCDA performance. This prompted further investigation and influenced the design of subsequent laboratory experiments.

BACKGROUND AND RESEARCH METHODOLOGY

While previous research conducted at the University of Washington provided significant insight into the performance of SCDAs, questions were also raised concerning the possibility of reducing the cost of using SCDAs and improving workability without compromising performance.

There are two objectives in the present research study. One is to determine if the cost of using SCDAs can be significantly reduced while maintaining an acceptable level of performance. The other is to assess the possibility of improving SCDA performance by developing a way of reducing the amount of water required. These objectives were considered independent of each other, and no effort was made to see if both could be achieved at the same time.

The tests were conducted in thick-walled steel cylinders with quarter bridge strain gauges attached on the outside circumference in order to measure the hoop strain. This procedure is identical to the other SCDA tests conducted at the University of Washington and is described in greater detail in a prior publication (Hinze and Brown 1994).

One of the major cost components in using SCDAs to demolish rock or concrete is the cost of the SCDA itself. One way to reduce the cost is to add an inert material to the SCDA mixture. This inert material acts as a filler in that it can displace some of the SCDA. If the inert material is relatively low in cost, then a more economical mixture is achieved. Of course, the concern is that the inert material can also reduce the performance of the SCDA. This was examined in experiments using clean sand as the inert material.

On a U.S. Army Corps of Engineers project, sand was added to an SCDA mixture that was being used to remove concrete from the walls of a large concrete structure. While the details of this effort are lacking, it appears that the sand was added to absorb some of the heat of hydration (Campbell

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Note. Discussion open until November 1, 1996. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this technical note was submitted for review and possible publication on June 13, 1995. This technical note is part of the ***Journal of Construction Engineering and Management***, Vol. 122, No. 2, June, 1996. ©ASCE, ISSN 0733-9364/96/0002-0193–0195/ $4.00 + $.50 per page. Technical Note No. 10914.

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1982). Results of this effort were apparently not entirely satisfactory. Note that the objective for adding sand to the SCDA on the Corps of Engineers project was different from the objective presented here.

The sand selected for this study was a commercially available fine aggregate that is commonly used in concrete. This was also the purpose for which the sand was typically used at the University of Washington. The Fineness Modulus, as determined by using the sieve analysis technique outlined in ASTM C136, was 2.76. The absorption rate of water was 2%, as determined by using the procedures outlined in ASTM C128.

Experiments were conducted with varying amounts of sand in the water/SCDA mixture. Of primary interest was whether the expansive pressure was reduced in direct proportion to the amount of sand in the mixture. When preliminary experiments involving small amounts of sand resulted in only minor reductions of expansive pressure, additional tests were conducted using even larger quantities. Final tests were conducted using mixtures consisting of 50% sand. All tests were conducted at an ambient temperature of 35°C and a water content of 31%. The computed water content of the SCDA/sand slurry did account for the water borne by the sand. Experimental controls were also used, which consisted of cylinders containing 100% SCDA.

The second objective was to explore the possibility of reducing the water content below 30%. For the specific SCDA being used, 30 to 34% was the recommended range of water content. The literature does not disclose whether this range is either optimal or if SCDA performance would decline outside of this range. Prior experimentation showed that greater expansive pressures were generated at the lower water levels. Unfortunately, at 30% water content, the workability of the SCDA mixture was very limited as the mixture was quite stiff. This made it difficult for the mixture to be poured into boreholes. Thus, the information being sought was whether the 30% lower limit was either determined by workability concerns or if this quantity of water was needed to fully hydrate the SCDA.

Since a lower water content was to be explored, and since workability was a concern, it was decided that experimentation should begin with the use of a superplasticizer in the SCDA mixture. When added to portland cement, superplasticizers act as water-reducing agents while improving the workability of wet concrete. This same principal was explored by using the superplasticizer in the SCDA mixture.

The superplasticizer selected was ASTM C494 Type F, commercially known as WRDA-19. This superplasticizer is commonly used for concrete mix designs requiring plasticizers. A Type F superplasticizer provides for a minimum of 12% water reduction at a rate of 350–600 mL per 45.35 kg (100 lb) of cement when designing a concrete mix. The upper limit (0.0132 mL/g) was selected for use with the SCDA.

When conducting the test with the superplasticizer in the SCDA mixture, the water content was lowered to 27.7%, a value well below the minimum suggested value of 30%. To be conservative in the computations, the volume of superplasticizer added to the SCDA was assumed to contribute that same volume of water to the mixture. The water contained by the superplasticizer is reflected in the 27.7% water/SCDA mixture. This test was conducted at a temperature of 35°C.

RESULTS

The "sand" tests were conducted with one control cylinder at 0% sand, and two cylinders with a common mix of 50% sand. The results showed that there was only a slight overall reduction in the performance of the SCDA. That is, the expansive pressure developed by the sand and SCDA mixture

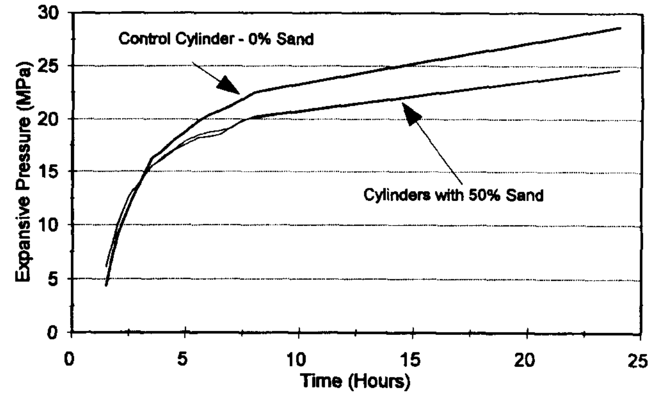

FIG. 1. SCDA Performance with 50% Sand Additive

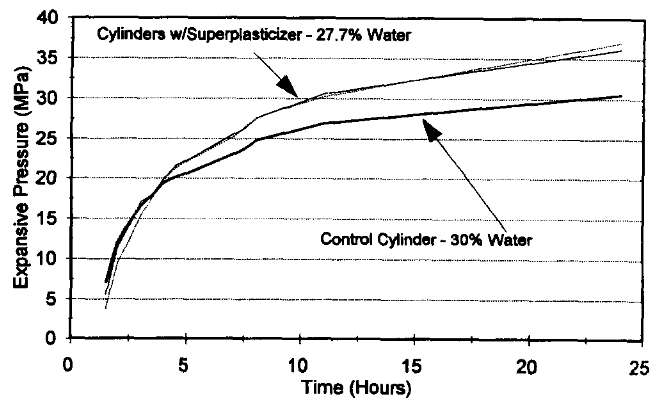

FIG. 2. SCDA Performance with Superplasticizer Additive

was only slightly less than that developed by the control cylinder having no sand. This was far more favorable than what would be anticipated from the introduction of an inert filler material.

Results show that even at 50% sand content, a significant expansive pressure is developed. In general, the expansive pressures rose quickly during the first 4 to 6 h. In the tests conducted, the pattern by which the expansive pressures were generated was similar between the control cylinder and the cylinders containing the sand additive.

The expansive pressures generated after 24 h were noticeably lower in those test cylinders containing sand, but the reduction was not proportional to the amount of sand contained in the mixture. After 24 h, the pressure generated in the control cylinder was 28.7 MPa, while the pressure attained in the cylinders containing the sand additive was about 24.6 MPa, a reduction of only 14% (see Fig. 1).

The tests involving the superplasticizer showed that higher expansive pressures were generated in these cylinders than in the control cylinder. Growth in pressure was similar for both the control cylinder and the cylinders containing the superplasticizer. After 24 h, the differences in pressure generated were more apparent. The control cylinder, with 30% water, developed an expansive pressure of 30.55 MPa at the end of the first day, while the cylinders containing the superplasticizer/SCDA mixture reached a 24-h pressure of approximately 36.6 MPa (see Fig. 2). It was also noted that the workability of the superplasticizer/SCDA mixture was better than that of the control mixture.

CONCLUSIONS

Research results show that SCDA performance is not unduly compromised by the addition of inert material, such as sand. It would therefore appear that the addition of sand to the

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SCDA mixture might be quite appropriate under certain circumstances. The rationale for adding sand or other inert material may be to reduce the cost of the demolition effort. It may also be to dissipate some of the heat of hydration in order to have greater control of the SCDA crystallization process.

The addition of the superplasticizer to the SCDA was effective in achieving a very workable slurry mixture at a water content that was lower than recommended by the manufacturer. At the same time, the generated expansive pressure was greater than that attained when the formulation was in accordance with the manufacturer's instructions. Clearly, the recommended lower level of 30% water content in the SCDA mixture is based on workability concerns rather than on optimal expansive pressure generation.

RECOMMENDATIONS

Contractors must recognize that the literature accompanying the SCDAs is often biased, and the performance characteristics may be misleading. Most product literature does not describe the testing environment under which the expansive pressures were measured. Neither does the literature allude to the fact that performance is extremely sensitive to ambient temperature and water content. The range of ambient temperature and the water content in which SCDAs are to be used are clearly noted, but no indication is given as to the extent that actual performance can vary when SCDAs are used within those ranges. Past research has clearly demonstrated that performance is best when the SCDAs are used at the higher end of the stated temperature range and at the lower end of the water content range.

The addition of clean sand to the SCDA slurry showed considerable promise as a means of reducing the cost of demolition with SCDAs. Further research is warranted to develop an envelope of performance when sand is added in differing quantities. This would enable practitioners to optimize the use of SCDAs. Research may also be warranted to examine the influence of using sand or aggregates of different sizes, and perhaps, some experimentation should be conducted with other inert materials.

In response to the research conducted on the use of superplasticizers, additional studies should be conducted in order to determine to what extent water content can be reduced while still maintaining workability through the introduction of an additional superplasticizer. Further studies would determine the appropriate quantity of superplasticizer to add to the SCDA mixture for optimal performance in terms of workability and generated expansive pressures.

Since the addition of sand only slightly impairs the performance of SCDAs, and since the addition of superplasticizers improves the performance of SCDAs, further research should examine the possibility of improving the total performance of SCDAs by the addition of both sand and superplasticizer. These two additives might very well prove that SCDA performance can be increased while reducing the overall cost.

ACKNOWLEDGMENT

The writers wish to thank Charles Schram of Western Project Management for his continued counsel on the use of SCDAs. We also express our sincere gratitude to him for contributing materials to perform the laboratory experiments.

APPENDIX. REFERENCES

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