How to Write a Good Technical Paper

Learn how to write easy-to-read technical papers

BY RACHEL J. DETWILER AND DAVID DARWIN

The ability to communicate is a critical skill that not only affects our success as professionals, but also determines how effectively lessons from the laboratory and field are transferred into general practice. As members of ACI's Publications Committee, and as authors ourselves, we offer some guidelines on one form of communication: writing technical papers. You can apply the principles we discuss to formal technical reports, reports to clients, conference papers, and journal articles. Publishing organizations prescribe the exact details of form and format.

The opinions expressed in this point of view article are not necessarily those of the American Concrete Institute. Reader comment is invited.

Because a technical paper should reconstruct the process of the investigation, the generic outline of a paper closely resembles the steps of the scientific method:

1. Identification of the problem or question to be investigated;
2. Evaluation of previous work in the field;
3. Formulation of the hypothesis or definition of the key aspects of the investigation;
4. Design of experiments, observations, or both;
5. Gathering of data;
6. Evaluation of data; and
7. Presentation of conclusions.

The technical paper

Writing the abstract

Concrete International doesn't include abstracts in its articles, but virtually all technical reports and journal papers lead off with an abstract. The abstract condenses the main ideas of the paper into a single paragraph (or several paragraphs for a long report). An informative abstract includes a summary of the investigation and the main findings.

The first sentence or two of the abstract should give the context of the investigation and the nature of the work. In other words, it tells why the study is relevant and of interest and what you investigated. The next two or three sentences should describe the scope of the work; that is, how and how many. Be specific without getting bogged down in details. The concluding sentence or two should present the main results and the implications of your findings. To pack so much content into a few sentences, be concise and avoid "padding." Don't use sentences from the body of your

paper in the abstract; in most cases, they won't be condensed enough.

Although the abstract appears first in a paper or a report, you should write it last. The reason is simple — most people continue formulating their ideas and conclusions while writing. Take time to write a good abstract. Because most people have far too much to read as it is, they read the abstract to see whether they should bother to read the rest of the paper. This may be your only chance to get their attention.

Introduction

The introduction gives the background information needed to establish the context of the investigation being reported. It normally includes:

1. A discussion of the problem, question, or controversy that led you to undertake the investigation: Why did you investigate this particular issue in this particular way?

2. A review of the relevant literature: The key word here is relevant. Be thorough, but include only those references that have a direct bearing on your work. An exhaustive review is usually neither necessary nor desirable in a journal article, although a more extensive review may be appropriate for a technical report. Show how previous developments provide the basis for your work. Be sure to re-read the articles you are citing to ensure that you quote them correctly, and don't read more into them than is supported by the evidence they present. Avoid biased or selective interpretation of results or conclusions; such interpretation is a disservice to both the authors you cite and your readers.

3. A statement of the objective(s) and purpose of your investigation: The hypothesis you are testing and the scope of your investigation may be stated explicitly or simply implied by the objective and purpose. A hypothesis, needed for most laboratory investigations, must be falsifiable; that is, it can be proven false by the type of evidence you set out to gather.

4. A statement of the research significance: Most papers in the *ACI Structural* and *Materials Journals* include an additional section that describes the significance of the research. While this information is usually included in the discussion of the problem, the use of a separate section is part of ACI style. By indicating why the results are important, you have an extra chance to grab the reader's attention.

Experimental work

This section describes the procedure(s) and materials in enough detail to allow someone else to duplicate your work. You may either provide the detail in the paper or refer to other sources, such as standard test methods published by a recognized standards writing body (ASTM, AASHTO, CSA, EN, RILEM) or another published article or report. If you deviate from a standard procedure, you need only describe the changes you made. If the procedures aren't likely to be accessible to the reader (for example, they are in a conference proceedings available only to those who attended the conference), include the details. In ACI Journals you can place extended information on materials, procedures, or apparatus in an unpublished appendix that's available from ACI.

Under any circumstances, make sure you present enough information so a reader who isn't familiar with the specific area of research can understand the broad design of your efforts. It's also wise to include key points that an expert in the field would check to establish the validity of your approach. Sketches and schematic diagrams of apparatus are often more helpful than photographs, if you need to describe it at all.

Results

This section presents the results and calculations. Consider how best to present the data. Engineers tend to prefer graphs to tables of numbers, but you may have a good reason to choose a table for your data. Pay attention to the way you present your results. Make sure your tables are neatly laid out, clear, and easy to read, and that they provide the information that the reader will need. Round off numerical values to the correct number of significant figures.

Be reluctant to eliminate outliers from your data. In general, data should not be removed or ignored unless there is a good reason for doing so. Mere deviation from your expectations, the replicate specimens, or results previously obtained by you or others is not a justification for eliminating data. Examine the specimens and procedures to see if some anomaly fully explains the results you obtained. Some types of measurements are prone to large scatter and require a large number of repetitions to give confidence in

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the result. In other cases, you may find that your experimental procedures are not defined sufficiently well to provide repeatable results; if so, your work is not ready for publication.

Don't automatically consider unusual results to be bad. Often, when additional research was completed, unusual results have been fully explained based on aspects of material or structural behavior that were not initially considered in the earlier investigations. Hiding results will come back to haunt you. Trust us!

Label graphs neatly and clearly (both axes and curves). In most cases, show data points explicitly, and draw curves smoothly. Don't include so much information that it becomes impossible to read.

Use photographs that are clear and large enough to allow the reader to see the details you are describing. Include a scale bar for micrographs, not just the magnification used, because the journal may change the size to fit the space available on the page. Photographs may also need some indication of scale.

Use brief but complete captions for tables and figures, because readers often look at them without referring to the accompanying text. In addition, tables and figures are sometimes extracted from the paper for use in other reports. Use captions, legends, callouts, or footnotes that contain all information necessary for correct interpretation of the tables and figures.

Discussion

The discussion is your evaluation and interpretation of the data: What do the results mean? How reliable are they? Do they lend support to existing theories? Do they tell us something new? Are they consistent with the results of previous work? What implications do they have for the reader?

Include the discussion with the results or place it in a separate section of the paper. In either case, it should follow logically from the results. The results and discussion together should build toward the conclusions; that is, the conclusions should not be a surprise but should be based firmly on the preceding text in the paper.

Summary and conclusions

Your final section may contain a brief summary of the work, and the conclusions may be presented in either a paragraph or a numbered list. Conclusions should follow logically from the results and discussion (we *are* repeating ourselves here). In most cases, it's best to list your conclusions in the order in which they appear in the paper or report. Occasionally, authors draw conclusions based on data they can't report publicly because of confidentiality agreements or court settlements. Reporting such conclusions is inappropriate because the reader can't examine the basis for them.

Write concise and well-written conclusions. Of course, the whole paper should be well written, but there is a practical reason to pay special attention to the conclusions. Busy readers generally look at the abstract first. If it attracts their interest, they turn to the conclusions next to see whether the findings warrant a careful reading of the rest of the paper.

Writing style

Good writing is clear and concise. You don't need to impress the reader with the size of your vocabulary or your ability to express a simple idea in the most convoluted (and tedious) way possible. Just say what you want to say as simply, clearly, and briefly as possible.

If you have a choice (that is, the journal you are writing for doesn't require it), prefer the active to the passive voice. Active verbs are livelier and call for simpler sentence structure. While you are writing, be aware of the style you are using — and don't switch styles in the middle of the paper. Be aware of verb tense, and use consistent verb tense when describing specific points in the study.

One tense, however, isn't always desirable. For example, the past tense is usually the most appropriate when describing the behavior of specific test specimens: "The specimen failed in shear." Make a general statement about the response of a material or structure in the present tense if the experimental results appear to be broadly applicable: "Members like this fail in shear." Results also can be described using the present tense: "The results demonstrate..."

After it's done

After you have completed your document, set it aside for a few days (or at least a few hours) and then re-read it from the point of view of a reader. As authors, we often become so intent on getting the basic information down on paper that we forget that we're really writing for an audience made up of nonexperts (at least in the details of our work). Make sure that these nonexperts can understand what you are trying to get across.

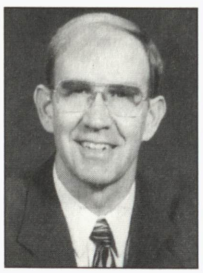
As you re-read your paper, feel free to cut extra words and add where amplification is needed. You probably will do far more cutting than adding. Change words such as "utilize" to "use," and be ruthless with "in order to," which can be changed to "to." As reviewers of many, many papers, we can testify that a significant

number of authors appear never to have re-read their papers. If they had, they surely would have removed such phrases as "...utilize the use of..." and "...an exothermic chemical reaction occurs which produces heat..." And finally, *always check for spelling errors.*

As authors, reviewers, and members of the ACI Publications Committee, our goal was to provide some guidelines on how to write high-quality technical reports and papers. We described the information that should be included and the key points to consider when writing each section. If you follow these guidelines, your final product will be greatly improved and well received by your readers.

Selected for reader interest by the editors.

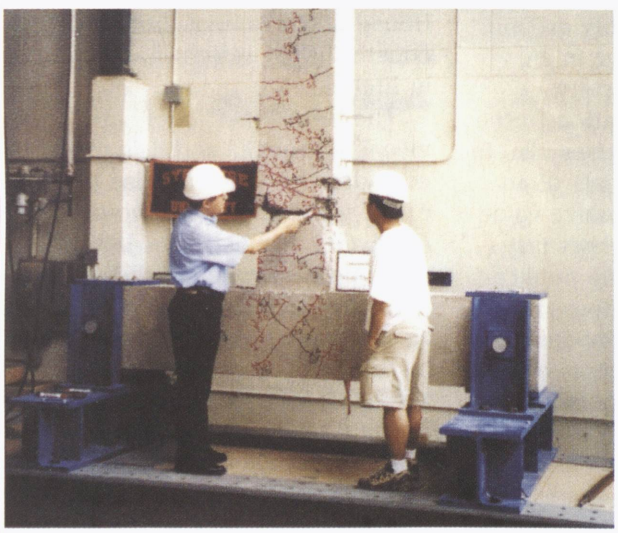
Rachel J. Detwiler, FACI, is principal engineer at Construction Technology Laboratories, Inc. in Skokie, Ill. She is chair of ACI Committee 227, Radioactive and Hazardous Waste Management; a member of 234, Silica Fume in Concrete; and the ACI Publications Committee.



David Darwin, FACI, is the Dean E. Ackers Distinguished Professor of Civil Engineering and Director of the Structural Engineering and Materials Laboratory at the University of Kansas. He is a member and former chair of the ACI Publications Committee.

New

Concrete Research Database



Did you know you can now share current research information through ACI's Concrete Research Database?

The Concrete Research Database (CRD) is maintained by ACI International to facilitate the exchange of current technology and research information among the concrete research community and industry leaders.

Researchers can post recently completed and on-going research projects on this website. Users are able to research the database using Keywords, Categories, and Project Status.

To access the Concrete Research Database, go to: www.aci-int.org/publications/research/database.

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If you have any questions, call 248-848-3730, fax 248-848-3720 or email research@aci-int.org.