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SPECIAL INTEREST GROUP FOR THE DYNAMIC EVALUATION OF ROOFING SYSTEMS Phase II

I. Summary

On Nov. 16, 1994, members of the roofing community met at the National Research Council of Canada and agreed that a means of evaluating the effect of dynamic wind loads on roofing systems was necessary. Thus, a *Special Interest Group on Dynamic Evaluation of Roofing Systems* (SIGDERS) was created in April 1995. SIGDERS combined the efforts of the National Research Council of Canada with those of the Roofing Community to build a facility and develop a protocol to evaluate the performance of roofing systems under dynamic wind loads. The aim of SIGDERS is to carry out generic, pre-competitive research of benefit to all its members. This project was intended to be a five-year initiative requiring only a commitment of two years for Phase I.

In the past two years, SIGDERS has met all the objectives established for Phase I. Namely, (a) build a facility (based on UEAtc guidelines) for the dynamic evaluation of roofing systems; (b) evaluate the validity of the UEAtc test protocol; and (c) characterize the mean and the dynamic properties of the wind loads. The facility can now facilitate the certification of roofing systems using the UEAtc standard -- "*Guideline for technical approvals of mechanically fastened roof waterproofing systems*". Furthermore, SIGDERS developed a dynamic test protocol. The SIGDERS load sequence is based on wind pressure records obtained from a unique wind tunnel study carried out at the NRC 30 ft by 30 ft wind tunnel using full scale roof systems (10 ft x 10 ft).

Phase II will require two years to be completed. During this time, it is proposed that SIGDERS: (a) develop a fast and inexpensive North American test protocol that replicates field conditions. Many establishments would then be able to employ this protocol to perform dynamic evaluations on roof systems. (b) build a facility to evaluate the thermal performance of roofing systems. It is anticipated that a third phase will be required to complete the following: (i) evaluate the effects of heat aging and testing temperature on the resistance to dynamic loads. (ii) develop a Design Manual for the roofing community. Completion of the overall project will require 4 years (Phase II and III combined).

The annual membership fee for Phase II will continue to be six thousand dollars ($6,000) Canadian funds and will require a commitment of two years ($12,000 total). Members of SIGDERS will automatically be eligible for membership in the Task Groups.

II. Phase I - Background

Existing test procedures for roof certification, such as the well-known FM (Factory Mutual) and UL (Underwriters Laboratories), are limited to static loading conditions. In reality, field wind conditions are dynamic. Thus, it is necessary to evaluate systems under dynamic loads. In 1994, the Institute for Research in Construction initiated a project entitled "*Dynamic Evaluation of Roof Attachment Systems*". It was designed to evaluate mechanically attached roof systems under dynamic wind loading. It was decided that test procedures and computer models would be developed for this purpose. Furthermore, the knowledge gained from these tests and analyses would be combined to produce a **Design Manual** for the roofing industry.

Five major tasks were identified: (1) Materials characterization, (2) Construction of a dynamic test facility for the evaluation of roofing systems, (3) Wind tunnel and laboratory measurements, as well as aerodynamic analysis, to establish appropriate wind loading histories, (4) Development of a computer model to predict roof performance under the assumed wind loading histories, (5) Development of a Design Manual based on the preceding work.

It was proposed that a joint research program be initiated to continue developing a protocol to evaluate roofing systems under dynamic loading. This partnership between industry, end-users, and the NRC will be of benefit to all involved. To ensure that the views of the roofing community are fully reflected in this program, *a Special Interest Group on the Dynamic Evaluation of Roofing Systems* (***SIGDERS***) was formed. The SIGDERS members in Phase I were:

Manufacturers	Canadian General Tower Ltd. / Prospex Roofing Products Ltd, Carlisle SynTec Systems, Cemfort Inc., Firestone Building Products Co., JPS Elastomerics Corp. - Construction Products Group, Soprema Canada, Vicwest Steel.
Building Owners	Canada Post Corporation, Department of National Defense, Public Works and Government Services Canada.
Industry Associations	Canadian Roofing Contractors' Association, National Roofing Contractors Association.
Research Agencies	Institute for Research in Construction, Institute for Aerospace Research.

SIGDERS concentrated on producing design and test procedures to evaluate and certify roofing systems under dynamic loads. The National Research Council of Canada is uniquely poised to assume the leading role in dynamic loading effects on roofing systems because of the resources and expertise of at least two institutes, the Institute for Research in Construction (IRC) and the Institute for Aerospace Research (IAR). The IRC is well known for roofing-related research and the production of the National Building Code of Canada. IRC also has an established reputation for assisting in the development of standards. IAR, formerly known as the National Aeronautical Establishment, is well known for aerodynamic research. Its 9 m x 9 m wind tunnel is the largest commercially accessible wind tunnel in North America. IAR has twenty years experience in wind-related roofing research and development, having prepared a widely used design manual for loose-laid roofing systems. The manual was based on wind tunnel measurements and mathematical analysis. This successful approach was extended to singly-ply roofing systems. The two participating institutes of NRC, in partnership with the roofing industry, brought a unique blend of expertise to bear on the roofing problem.

III. Phase I - Accomplishments

In the past two years of Phase I, SIGDERS had six formal technical meetings at NRC and fulfilled all established objectives. Namely, (a) build a facility (based on UEAtc guidelines) for the dynamic evaluation of roofing systems; (b) evaluate the validity of the UEAtc test protocol; and (c) characterize the mean and the dynamic properties of the wind loads. Accomplishment details are documented through minutes of the meetings, audio-visual documents, technical reports, conference presentations and peer reviewed technical papers. Section X lists some of these publications.

The specific accomplishments are as follows:

- A dynamic roofing facility was established for the North American roofing community. It was commissioned to evaluate roofing systems for different loading sequences including the UEAtc test procedure.
- Two major wind tunnel studies were carried out with full-scale roof systems (PVC and EPDM membranes) measuring 10 ft by 10 ft.
- A new dynamic test protocol was developed using the wind tunnel pressure records and it took less time than the UEAtc test procedure.
- Investigations were completed on four typical single-ply roofing systems, reinforced PVC, reinforced EPDM, TPO and modified bitumen with three load sequences (FM, UEAtc and SIGDERS).
- Comparison of the design wind pressures and fastener forces, although limited to the tested roof assemblies, indicated the benefit of the dynamic evaluation.

IV. SIGDERS Phase II - Objectives

The main objectives for the next two years of the program were identified as follows (these draft objectives are subject to modification by the steering committee):

1. Develop a North American wind uplift test protocol that is fast, inexpensive and replicates field conditions. Many establishments would then be able to employ this protocol to perform the evaluations. Bench mark data will be collected to fulfill this objective on several systems through investigation for the effect of system parameters on the dynamic evaluation.
2. Build a facility for the thermal performance evaluation of roofing systems. The facility will then be used for heat aging, thermal freezing and combined wind and thermal effects on the roofing systems.
3. Initiate standards (e.g., CGSB and ASTM) and design manual for the dynamic evaluation of roofing systems.

Although the exact deliverables will be discussed at the committee level, it is understood that actual dynamic wind loads failures should be duplicated in a laboratory environment and a design manual or technical guide be written for the general public.

V. Membership Fee and Duration of Joint Research Program

The annual membership fee will be six thousand dollars ($6,000) in Canadian funds payable in semi-annual installments of $3,000. Membership will require a commitment of two (2) years. These two years will be required to implement the thermal effects on the dynamic test facility and establish the protocol for the evaluation of the resistance of roofing systems to dynamic wind loads as well as thermal loads. Membership privileges include Task Group membership and first access to the information developed.

VI. Task Groups and Steering Committee

The Steering Committee will meet at least twice a year and it will consist of all the members of SIGDERS. Although any member may send more than one representative, each member will only have one vote. It will be the responsibility of the Steering Committee to develop the research program, establish the project schedule, and set the major milestones for the agreed deliverables. The Steering Committee, through the auspices of the NRC, will prepare and circulate minutes of the Steering Committee and Task Group meetings, and will provide annual financial and progress reports to its members.

VII. Benefits to the Members of SIGDERS

Members would profit in several ways, including:

- Publicity through acknowledgment on research reports and technical papers.
- Providing advice in establishing the facility, test protocols and development of standards aimed at evaluating roofing systems under dynamic wind loads.
- Participating in the Task Groups of SIGDERS.
- Providing input in the development of the Design Manual.
- Participating in the semi-annual reviews (which will include technical presentations) and receiving the associated interim technical reports.
- Having access to NRC technical staff. Members would be briefed on all NRC roofing-related research developments.
- Having first access to the technical information developed. Technology transfer is the main goal of the project.
- Receiving a 20% discount for roofing membrane and system testing pertinent to the protocol (e.g., UEAtc, T_g, SIGDERS). This discount will apply up to two (2) years after the end of membership in SIGDERS.

VIII. Description of Proposed Facility and Protocol

. The following description is offered to stimulate discussion. It is a draft that is subject to change by the SIGDERS Steering Committee and Task Groups.

The SIGDERS facility will be upgraded to include a thermal effect on the roof systems. The enhancement would not interrupt on-going activities; that is to say, the thermal facility would be independent of the existing facility, although interchangeable with it. Thus the overall size of the facility is will be of same size as that of the existing SIGDERS facility. The proposed facility could be used in the following ways. Investigate the effects of heat-aging/weathering of roof assemblies. This will be facilitate static heat aging mode, with roof surface temperature up to 100°C (212°F). and static cooling mode, with roof surface temperature down to -30°C (-22°F). In addition, wind cycles developed in the SIGDERS Phase I (representing the appropriate unsteady wind loads) will be simulated to quantify interaction of wind and thermal stresses.

To reduce travel cost, advancement in communication technology for video transmission through WWW Internet site will be explored. This will facilitate SIGDERS members to witness the testing process from their office using PC workstations.

IX. Personnel

The following NRC personnel will participate in the program:

Dr. Bas A. Baskaran, Research Officer and Project Leader,
Ph.D., Engineering, Concordia University, Montreal, QC, 1990.

Dr. Ralph M. Paroli, Researcher and Roofing Activity Leader,
Ph.D., Chemistry, McGill University, Montreal, QC, 1988.

Dr. Karen Liu, Research Officer,
Ph.D., Engineering, University of Toronto, Toronto, ON, 1997.

Dr. Yin Chen, Research Associate,
Ph.D., Engineering, Memorial University, St. John's, NFLD, 1996.

Mr. Michael Savage, Research Officer,
B.Eng., Carleton University, Ottawa, ON, 1983.

Mr. William Lei, Technical Officer,
B.ASc., (Chemical Engineering), Ottawa University, ON, 1987.

Ms. Ana H. Delgado, Technical Officer,
M.Sc., Carleton University, Ottawa, ON, 1985.

Ms. Jayne D. Irwin, Technical Officer,
B.ASc. (Chemical Engineering), Ottawa University, ON, 1995.

Ms. Doreen G. Charron, Secretary

X. Publications from the SIGDERS Research Project

1. Baskaran. A., Chen. Y., *"Wind Load Cycle Development for Evaluating Mechanically-Attached Single-Ply Roofs"* Paper accepted for the Eighth US National Conference on Wind Engineering, Baltimore, June 5-7, 1997.

2. Baskaran. A., Lei. W., *"A New Facility for Dynamic Wind Performance Evaluation of Roofing Systems"* Paper accepted for the Fourth International Symposium on Roofing Technology, Washington, September 17 -19, 1997.

3. Baskaran. A, Paroli. R.M, Booth. R.J., *"Wind Performance Evaluation Procedures for Roofing Systems - Current Status and Future Trends"*, Proceedings of the ICBEST -97 Conference, Bath, UK, April 15-17, 1997.

4. Baskaran. A, Chen. Y and Savage. M.G., *"Development of a Wind Load Cycle for Testing Commercial Building Envelopes"* Proceedings of the ASCE 1997 Structures Congress Conference, Portland, Oregon, April 14-17, 1997.

5. Baskaran, A.; Kashef, A.; Savage, M.G. *"Wind Performance Evaluation of Roofing Systems Using Numerical Models"*, Submitted to: Journal of Computers and Structures pp. 1-33., May, 1996

6. Baskaran, A.; Frégeau, C. "Roofing systems and their performance requirements" pp. 1-20, 1996 (Reprinted in Building Better Roofs : IRC Technical Seminar (NRCC-40627))(

7. Baskaran, A., "New research investigates the effects of dynamic wind loads on roofing systems": Journal of the Roofing Consultants Institute - Interface pp. 8-12, October 1996.

8. Koroluk, K. "North American standard wanted : group concerned about performance of roofing

systems under dynamic wind loads" *Daily Commercial News and Construction Record* 68(146), 1995 pp. 2-3. (NRCC-38835)

9. Chen. Y and Baskaran. A, Development of Load Sequence using Pressure Records Measured from Wind Tunnel Studies for Mechanically Attached Single -Ply PVC and EPDM Roofs" 66 pp. (Internal Report 743, Institute for Research in Construction, National Research Council Canada, June 1997.

10. Baskaran, A, Savage, M.G., Alfawakhiri. F and Cooper, K.R. Fastener Load Data Measured During the November 1994 Wind Tunnel Tests on a Mechanically Attached EPDM Single Ply Roofing Systems 68 pp. (Internal Report 742, Institute for Research in Construction, National Research Council Canada, May 1997.

11. Baskaran, A, Savage, M.G., Alfawakhiri, F and Cooper, K. Fastener Load Data Measured During the October 1995 Wind Tunnel Tests on a Mechanically Attached PVC Single Ply Roofing Systems 53 pp. (Internal Report 740, Institute for Research in Construction, National Research Council Canada, May 1997.

12. Baskaran, A, Savage, M.G., Alfawakhiri, F and Cooper, K. Pressure Distribution Data Measured During the October 1995 Wind Tunnel Tests on a Mechanically Attached EPDM Single Ply Roofing Systems 203 pp. (Internal Report LTR A 004, Institute for Aerospace Research, National Research Council Canada, July 1996.

13. Savage, M.G., Baskaran, A., Cooper, K.R., Lei, W. Pressure Distribution Data Measured During the November 1994 Wind Tunnel Tests on a Mechanically Attached PVC Single Ply Roofing Systems 132 pp. (Internal Report LTR A 003, Institute for Aerospace Research, National Research Council Canada, Feb 1996.

14. Baskaran, A. and Dutt, O. "*Evaluation of Roof Fasteners under Dynamic Wind Loading*", Proceedings of the Ninth International Wind Engineering Conference, January 9–13, 1995.

15. Baskaran, .A., Kashef, A. Application of Numerical Models for the Dynamic Evaluation of Roofing Systems. Part 1: Review of the State-of-the-Art 43 pp. (Internal Report 692, Institute for Research in Construction, National Research Council Canada, May1995.

16. Baskaran, A., Dutt, O. Application of Lab Procedures for the Dynamic Evaluation of Roofing Systems. Part 1: Review of Existing Standards, 1995. 26 pp. (Internal Report 690, Institute for Research in Construction, National Research Council Canada, May 1995

17. Baskaran, A., Dutt, O. "Putting roof fasteners to the test in high winds" RSI : Roofing Siding Insulation 71(1), 1994.

18. Baskaran, A., Dutt, O.; Paroli, R.M. "Keeping mechanically attached roofs on in high winds" Construction Canada 36(4), 1994 pp. 22-24.