# *S*uper *M*atrix *S*olver-BEM(SMS-BEM):

## High-Speed Matrix Solver based on Boundary Element Method dedicated for Dense Matrices

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**URL: http://www.vinas.com**

# Special Feature of SMS-BEM

- Dedicated to dense matrices that are generated with boundary element method (BEM).
- Hybrid-Solver with pre-processing based on direct and iterative methods.
- Up to 40 times faster compared with direct method.
- Less memory usage: size of required memory about 1.1 to 1.3 times the size of coefficient matrix A.
- Calculation time increase in squares of the size of coefficient matrix A (c.f. calculation time increase in cubes with direct method)
- Out-of-Core capability with efficient control of Disk I/O
- Adjustable calculation accuracy (iterative method allows for configuration of convergence criteria).

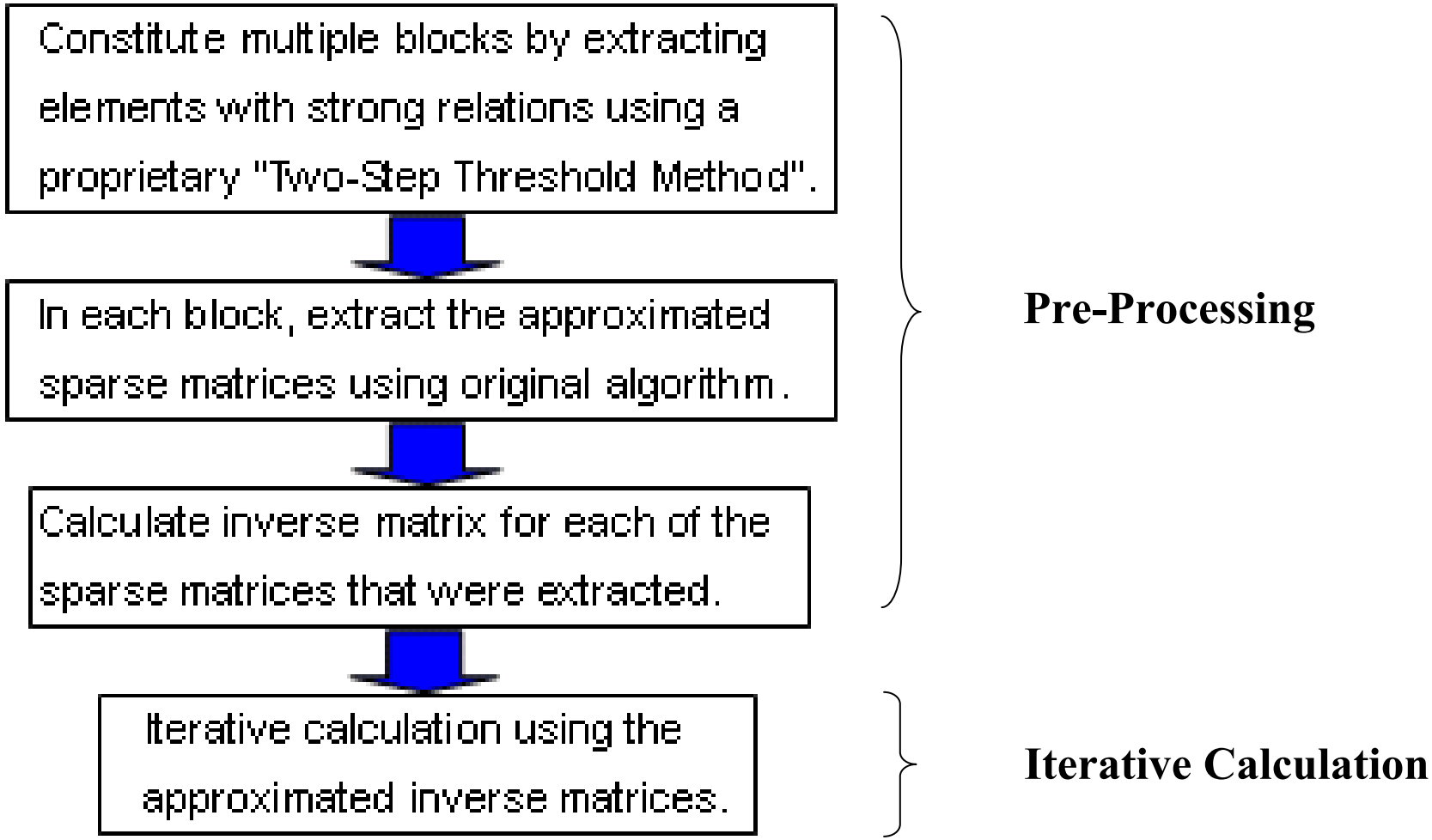
# SMS-BEM Summary Specification (1)

| Items | Descriptions | Notes |
|---|---|---|
| Intended Matrix | Dense matrix generated with Boundary Element Method (BEM) | Full matirx |
| Types of Unknown | Real (double-precision) and Complex Numbers | |
| Solution Method | Pre-processing + Iterative Method | |
| Operation Environment | Windows, Linux | For UNIX environment, please contact VINAS. |
| Data Giving Method<br><br>Out-of-Core Capability → | 1. In-Core calculation (with actual memory only):<br>Giving coefficient matrix ***A***, right-hand-side vector ***b*** as arguments.<br>The result is also returned as arguments.<br><br>2. Out-of-Core calculation (with actual memory and disk):<br>Dump the coefficient matrix ***A*** once into a file before loading the data.<br>Right-hand-side vector ***b*** is given as arguments.<br>Results are also returned as arguments. | 1. for small to medium size problems (with fewer than 14,000 unknowns)<br>2. for large size problems (that exceeds 14,000 unknowns (2GB RAM real data )s<br><br>Calculates 14,000 unknowns with 2GB memory on PC! |
| Parameters | 1) Target Convergence<br>2) Number of Iteration<br>3) Amount of memory that can be allocated to the solver (in case of Out-of-Core) | 1 and 2 must be assigned because the solution method is based on iterative method.<br>Target convergence is specified as relative residual in L2 norm. |

# SMS-BEM Summary Specification (2)

| Items | Descriptions | Notes |
|---|---|---|
| Other Conditions | 1. Enter coefficient matrix ***A*** as 1D array when giving data as arguments.<br>Dump the data so that the ith column and jth element of the coefficient matrix ***A***, and the kth element of ID array relate as follows:<br>k=( i-1）*n+j (where n is the number of unknown)<br>2. When reading from a file, enter the data of coefficient matrix ***A*** row by row. | Enter the data row by row in a sequence (enter the elements of the 1st row, then the 2nd row, and so forth). |
| Data Format | DLL Format, Static Library Format | No disclosure of the source code. |
| License Type | Node Lock Type | Available for a fixed machine. |
| Memory Requirement Estimation | For In-Core calculation, memory addition is required that is 0.1 to 0.3 times as large as the size of the coefficient matrix ***A***.<br>(i.e. for the matrix size of ***S***, the size of required memory is 1.1***S*** to 1.3***S***).<br><br>Out-of Core calculation with small amount of memory (e.g. 1/10 or smaller the size of coefficient matrix ***A***). However, larger the amount of memory allocated, faster the calculation speed.<br>When the amount of memory allocated is small, the calculation may not converge depending on problems. | **Breakthrough in memory requirement that is only 1.1 to 1.3 times the matrix size!** |
| Calculation Time | For In-Core calculation, calculation time increase is proportional to the square of the size of coefficient matrix ($N^{2,}$ , where N is the number of unknown). | **c.f.) calculation time increases in cubes in conventional direct method solver** |

# SMS-BEM Calculation Flow

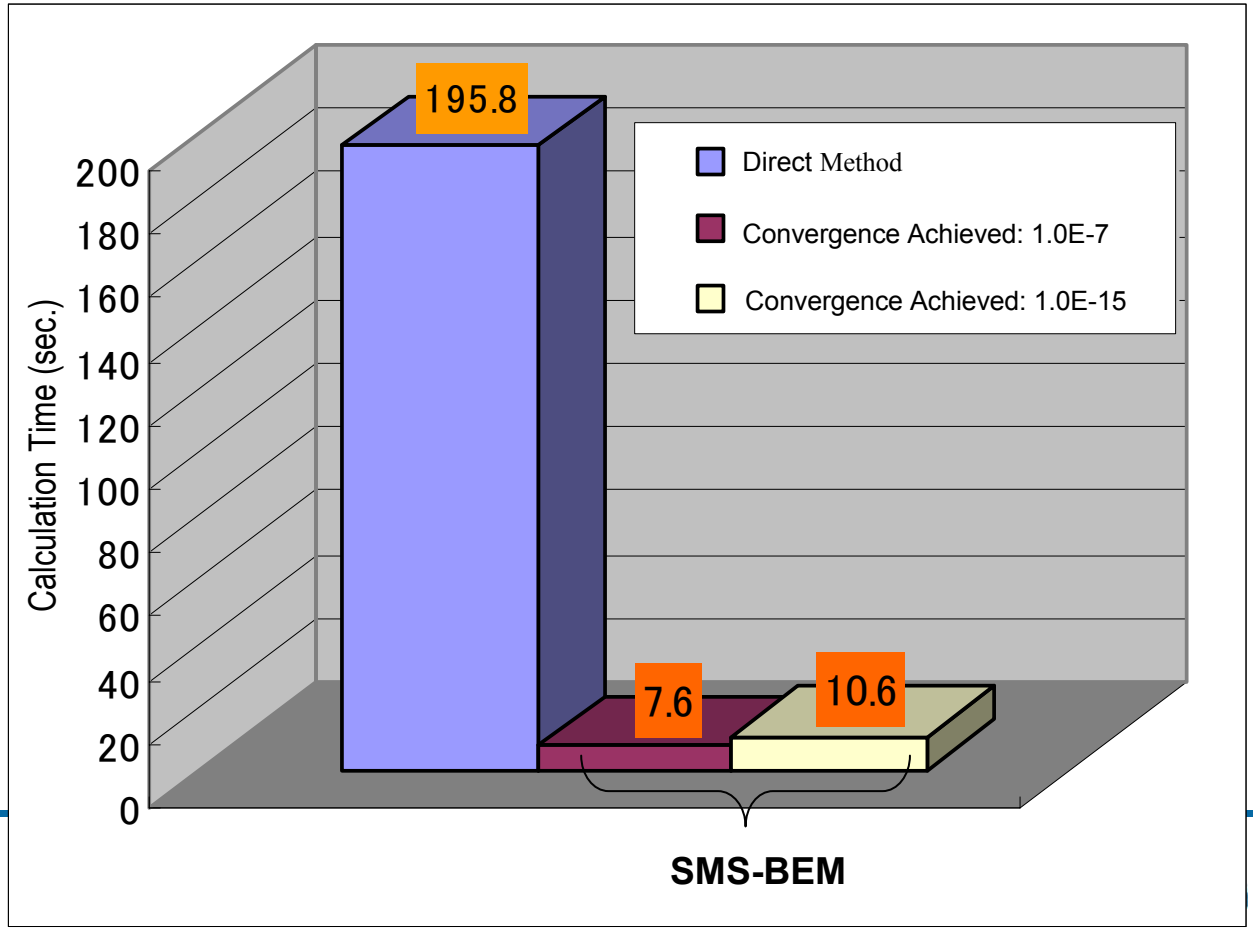


# SMS-BEM Calculation Example

- Field of Application
  CFD
- Size of Problem
  4,100 unknowns
- Calculation Environment
  CPU: Xeon 3.06GHz
  Memory: 2GB

Calculation Time (sec.)

| LU Decomposition Method | SMS-BEM | | Ratio (Tdirect/Tsms-bem) |
|---|---|---|---|
| Calculation Time (Tdirect) | Calculation Time (Tsms-bem) | Convergence | |
| 195.8 | 7.6 | 1.00E-07 | 26 |
| | 10.6 | 1.00E-15 | 18 |

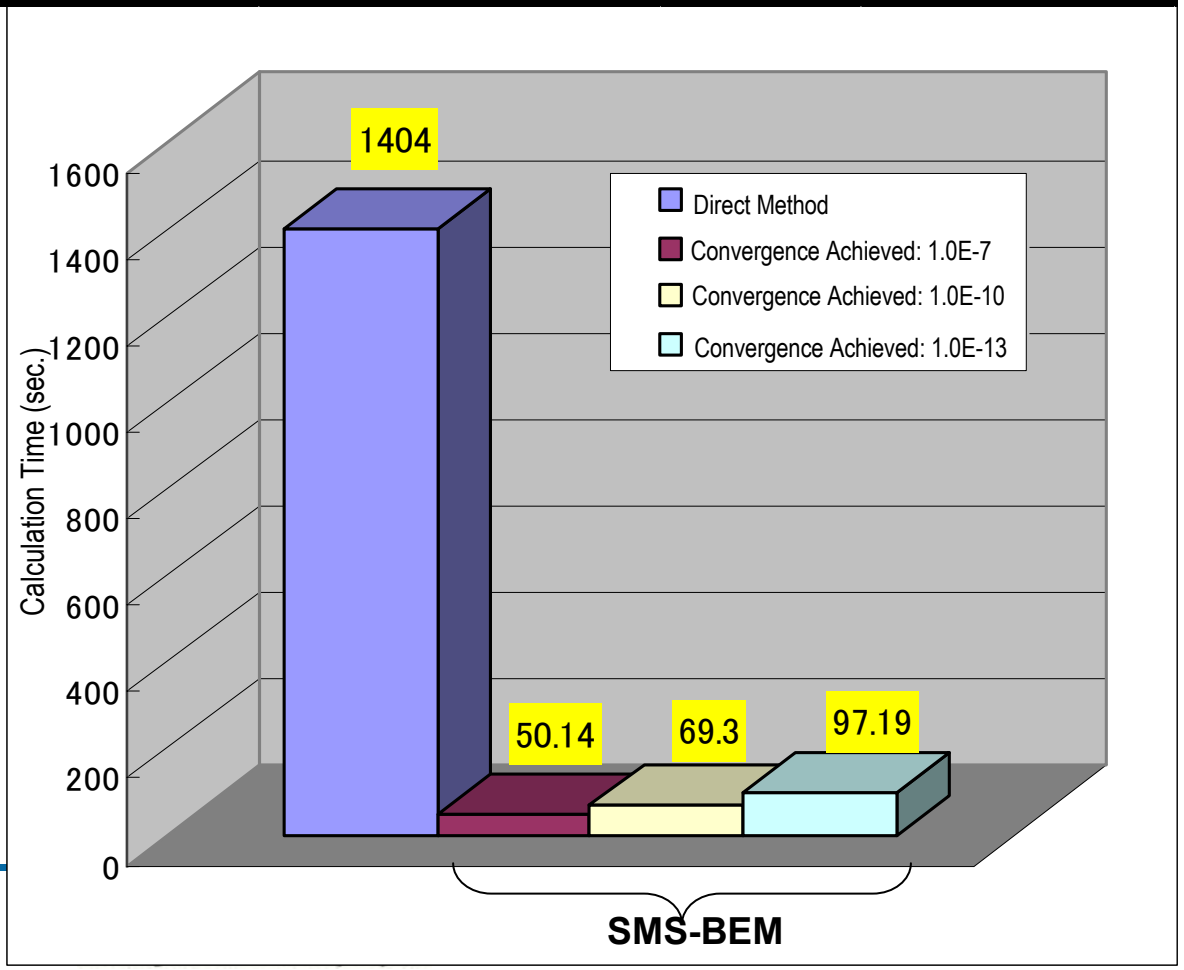


# SMS-BEM Calculation Example

- Field of Application
  Electromagnetic Analysis
- Size of Problem
  6,000 unknowns
- Calculation Environment
  CPU: Pentium4 1.8GHz
  Memory: 1GB

Calculation Time (sec.)

| Direct Method | SMS-BEM | | |
|---|---|---|---|
| Calculation Time ($T_{direct}$) | Calculation Time ($T_{sms-bem}$) | Convergence | Ratio ($T_{direct}/T_{sms-bem}$) |
| 1404 | 50.14 | 1.00E-07 | 28 |
| | 69.3 | 1.00E-10 | 20 |
| | 97.19 | 1.00E-13 | 14 |

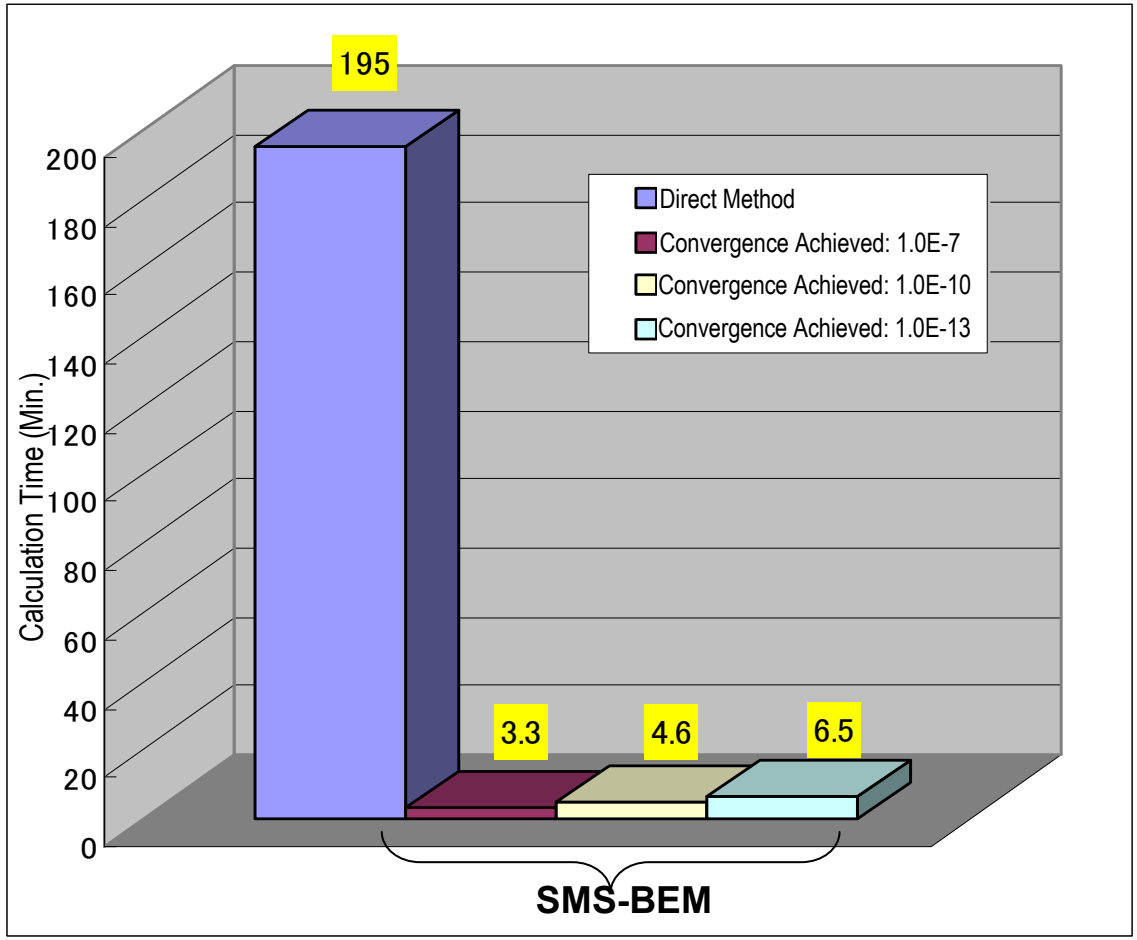


# SMS-BEM Calculation Example

- Field of Application
  Electromagnetic Analysis
- Size of Problem
  13,000 unknowns
- Calculation Environment
  CPU: Pentium4 2.4GHz
  Memory: 2GB

Calculation Time (Min.)

| Direct Method | SMS-BEM | | Ratio ($T_{direct}/T_{sms\text{-}bem}$) |
|---|---|---|---|
| Calculation Time ($T_{direct}$) | Calculation Time ($T_{sms\text{-}bem}$) | Convergence | |
| 195 | 3.3 | 1.00E-07 | 59 |
| | 4.6 | 1.00E-10 | 42 |
| | 6.5 | 1.00E-13 | 30 |



# Environments supported by SMS-BEM

Rev A: November 10, 2010

| | OS | Recommended Environment | Recommended Compiler | Environment for which operation is noted | Compilers for which operation is noted | Remarks |
|---|---|---|---|---|---|---|
| 32-bit machine | Windows | Windows 2000<br>Windows XP | (1)Fortran<br>・Intel Fortran 9.1 and later<br>(2) C / C++ language<br>・Microsoft Visual Studio 2005<br>・Microsoft Visual C++ 2005 and later | | ・Intel Fortran 9.0 | |
| | Linux | Red Hat Enterprise Linux 4<br>gcc : 3.4.6<br>glibc : 2.3.4<br>kernel : 2.6.9 | gcc 3.4.6<br>Intel Fortran 9.1 and later | | ・Intel Fortran 9.0 | Environment under which the module might operate:<br>gcc 3.4.6 and later,<br>glibc 2.3.4 and later,<br>kernel 2.6.9 and later |
| 64-bit machine | Windows (AMD64/ EM64T) | Windows XP x64 | (1)Fortran<br>・Intel Fortran 9.1 and later<br>(2) C / C++ language<br>・Microsoft Visual Studio 2005<br>・Microsoft Visual C++ 2005 and later | | ・Intel Fortran 9.0 | |
| | Linux (AMD64/ EM64T) | Red Hat Enterprise Linux 4<br>gcc : 3.4.6<br>glibc : 2.3.4<br>kernel : 2.6.9 | gcc 3.4.6<br>Intel Fortran 9.1 and later | | ・Intel Fortran 9.0 | Environment under which the module might operate:<br>gcc 3.4.6 and later,<br>glibc 2.3.4 and later,<br>kernel 2.6.9 and later |

# Double-Precision Real Numbers

## Calling for In-Core Calculation:

➢rtc=smsbemd( u, abrs, nstp, a, b, nd, mstp, eps )

## Calling for Out-of-Core Calculation:

➢rtc=smsbemd_out( u, abrs, nstp, b, nd, mstp, eps )

**List of Arguments**

| Argument | Type | Description |
|---|---|---|
| u | real*8 | Solution |
| abrs | real*8 | Achieved accuracy in relative residual (L2 norm) |
| nstp | integer*4 | Actual number of iterations |
| a | real*8 | Coefficient matrix ***A**** |
| b | real*8 | Right-hand-side constant vector ***b*** |
| nd | integer*4 | Number of unknowns |
| mstp | integer*4 | Maximum number of iterations |
| eps | real*8 | Required accuracy in relative residual (L2 norm) |

*Coefficient matrix ***A*** is given as a file in case of the Out-of-Core Calculation.
Please refer to the Product Manual for detailed information.

# Double-Precision Complex Numbers

## Calling for In-Core Calculation:

➢rtc=smsbemc( u, abrs, nstp, a, b, nd, mstp, eps )

## Calling for Out-of-Core Calculation:

➢rtc=smsbemc_out( u, abrs, nstp, b, nd, mstp, eps )

**List of Arguments**

| Argument | Type | Description |
|---|---|---|
| u | complex*16 | Solution |
| abrs | real*8 | Achieved accuracy in relative residual (L2 norm) |
| nstp | integer*4 | Actual number of iterations |
| a | complex*16 | Coefficient matrix ***A**** |
| b | complex*16 | Right-hand-side constant vector ***b*** |
| nd | integer*4 | Number of unknowns |
| mstp | integer*4 | Maximum number of iterations |
| eps | real*8 | Required accuracy in relative residual (L2 norm) |

*Coefficient matrix ***A*** is given as a file in case of the Out-of-Core Calculation.
Please refer to the Product Manual for detailed information.

For further information on SMS-BEM such as

•Benchmark Testing (BMT)

•Evaluation module

•Other inquiries

## Please contact:

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