CONSTRUCTION AND APPLICATION OF A NATIONAL DATA-SHARING SERVICE NETWORK OF MATERIAL ENVIRONMENTAL CORROSION

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ABSTRACT

This article discusses the key features of a newly developed national data-sharing online network for material environmental corrosion. Written in Java language and based on Oracle database technology, the central database in the network is supported with two unique series of corrosion failure data, both of which were accumulated during a long period of time. The first category of data, provided by national environment corrosion test sites, is corrosion failure data for different materials in typical environments (atmosphere, seawater and soil). The other category is corrosion data in production environments, provided by a variety of firms. This network system enables standardized management of environmental corrosion data, an effective data sharing process, and research and development support for new products and after-sale services. Moreover this network system provides a firm base and data-service platform for the evaluation of project bids, safety, and service life. This article also discusses issues including data quality management and evaluation in the material corrosion data sharing process, access authority of different users, compensation for providers of shared historical data, and finally, the related policy and law legal processes, which are required to protect the intellectual property rights of the database.

Keywords: Data-sharing, Environmental corrosion, Corrosion test site, Atmospheric corrosion, Seawater corrosion, Soil corrosion, Materials data

1 BACKGROUND

Environmental corrosion or aging of materials is at the interface between materials science and environmental science. Environmental corrosion data for different materials have been accumulated from several corrosion test sites constructed in different natural environments. In these projects, various samples were manufactured from different materials in accordance with international or national standards and put into natural environments to investigate the environmental factors and their influence on the performance of materials. Using different sampling periods, the specimens have been examined to obtain raw data and related information for different materials. Through data evaluation, data processing, and comprehensive analysis, the corrosion rules for performance of various materials in different environments can be determined. Furthermore, the database and its application system can provide a scientific basis for developing standards and criteria for corrosion-resistant (or aging-resistant) materials, which are very helpful for material design and selection, and the improvement of material quality and performance.

The construction of a material environmental corrosion data-sharing network (MECDSN) is the key point in the study of material environmental corrosion data-sharing, the basis of which is data accumulated over a long period and collected from a national material environmental corrosion experiment site network. With the aid of an internet platform, MECDSN has achieved three objectives: resource-sharing from each experimental site, online data-sharing in the field of material environmental corrosion, and a relevant consultation service. The establishment of a sharing system and the website for material environmental corrosion improves the public understanding of the necessity for MECESN and is of great help in increasing the value of the data. That is, the data can be applied to different industries and further promote the data renewal and exchange, which are also driving forces for the future work of MECESN. The aim of this project is to establish 28 national experimental sites for materials environmental corrosion and the related website for data sharing. In this way corrosion data can be shared on a large scale, and the relevant data services can be further developed by exploring the database functions. Finally, this project will enhance the level of theoretical research in the field of materials environmental corrosion and the application and development of database for China.

The data-sharing network service of materials environmental corrosion meets the requirements of national construction departments, material manufacturers and materials users, as well as the standardization administration of China. Specifically, corrosion failure data in different environments are an important reference in the design of key construction projects and are regarded as very important by the national export and import departments. However, the data of materials environmental corrosion that are currently available are not used effectively, so their full value is not achieved. The reason can be attributed to the Chinese traditional model of thinking, and also to the technical profiles. Therefore, the construction of the data-sharing network is an essential way to effectively realize the value of the data.

2 FUNDAMENTAL CONDITIONS

In the late 1950s, many researchers started to collect and accumulate environmental corrosion data. The corrosion behavior of materials varies significantly in the diverse environments across the vast geographical areas of China, consisting of seven climatic zones, four marine regions and over 40 types of soil. By 2005, a network for data accumulation had been constructed consisting of 13 atmospheric corrosion test sites, 7 seawater corrosion test sites, and 8 soil corrosion test sites, as shown in Figure 1. These sites were selected and built up based on over 50 experimental sites involving different industries. Since 1982, 353 kinds of materials have been tested, containing more than 93000 specimens. Through four cycling period experiments and observation, more than 400 thousand data points have been collected; these include corrosion and aging data of classical materials for various environments, as well as the relevant environmental data, shown in Table 1. In addition, the corresponding database had been constructed, the structure of which is shown in Figure 2. These data have been employed in many key projects such as Qinshan nuclear station project, Sanxia Dam project and BaoSteel project (Luo & Li, 2005; Wang, Li, & Luo, 2002). In addition, many steel enterprises made use of them to improve the properties of traditional products and develop new material products. Based on these data, the corrosion principles and the corrosion-resistant performance of different materials in various environments have been summarized, which provide criteria for material selection and the estimation of corrosion performance. In 2002 and 2003, there were 178 kinds of material, and a total of 14904 specimens put into tests, as shown in Table 2.

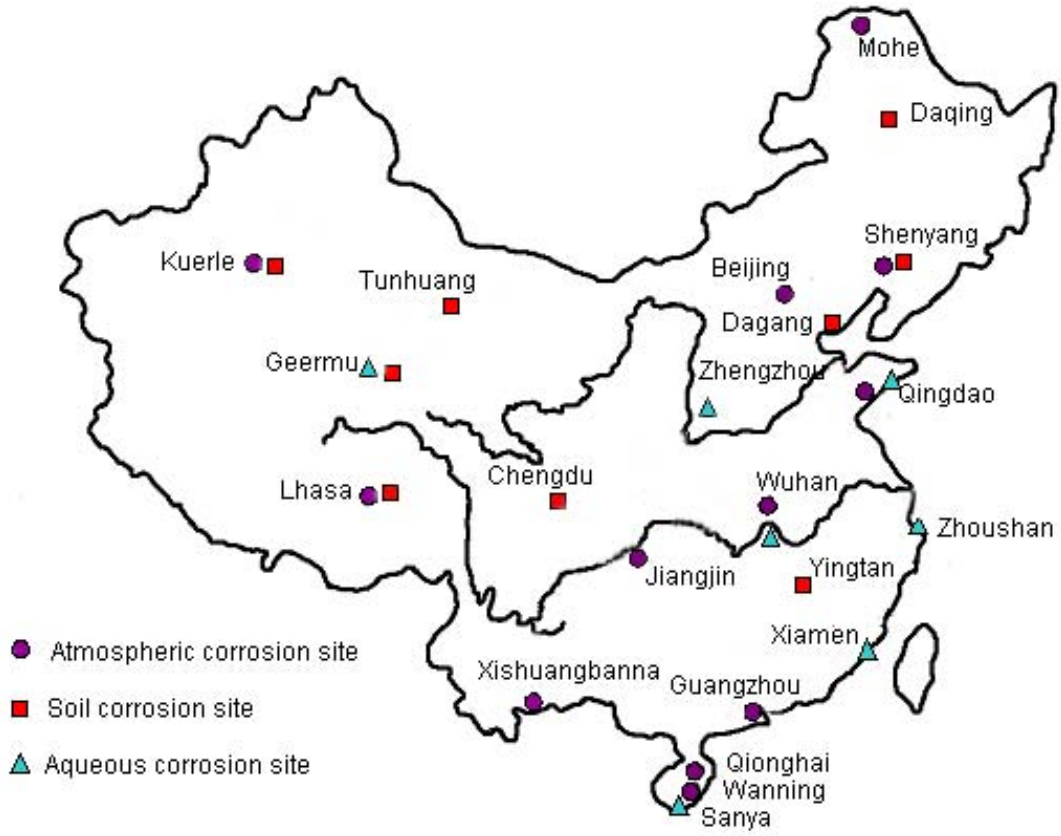

Figure 1. Site distribution map of the national network of material environmental corrosion

Table 1. Materials put into test by the national network of material environmental corrosion **(**Wang, Li, & Luo, 2002)

Network of Test site	General Category	Specific Type	Number of Types	Amount of Samples (piece)
Network of Atmospheric Corrosion Test Sites	Ferrous Metal	Carbon Steel, Low Alloy Steel, Stainless Steel	22	
	Nonferrous Metal	Copper, Aluminum, Titanium & Their Alloys	28	
	Protective Layers	Plated Metallic Layers & Organic Coatings	60	
	Polymer Material	Plastics, Rubbers, Paints & Adhesives	134/38	
	Sum	4 categories	244/38	59925
Network of Seawater Corrosion Test Sites	Ferrous Metal	Carbon Steel, Low Alloy Steel, & Stainless Steel	24	
	Nonferrous metal	copper, Aluminum, Titanium & Their Alloys	31	

	Plated/Coated Layers	Sprayed/Plated Metallic Layers & Organic Coatings	16	
	Sum	3 categories	71	11591
Network of Soil Corrosion Test Sites	Ferrous Metal	Carbon Steel (pipe, sheet) & Stainless Steel	6	
	Nonferrous Metal	Copper, Aluminum & Lead	3	
	Inorganic Material	Cement, Asbestos Cement & Concrete	7	
	Polymer Material	Plastics, Pitch, Oiliness Hemp, Pyrocondensation Tube	7	
	Cable and Protective Layers	Urban Cables, Rural Cables, Coaxial Cables, Plastic Cable, Bare Lead and Alumna Painted Steel Belt, Plastic-coated Steel Wire	13	
	Optical Cable and Protective Layers	Optical Cables for Local and Long Distance Calls	2	
	Sum	6 categories	38	673
Total Amount			353	93237

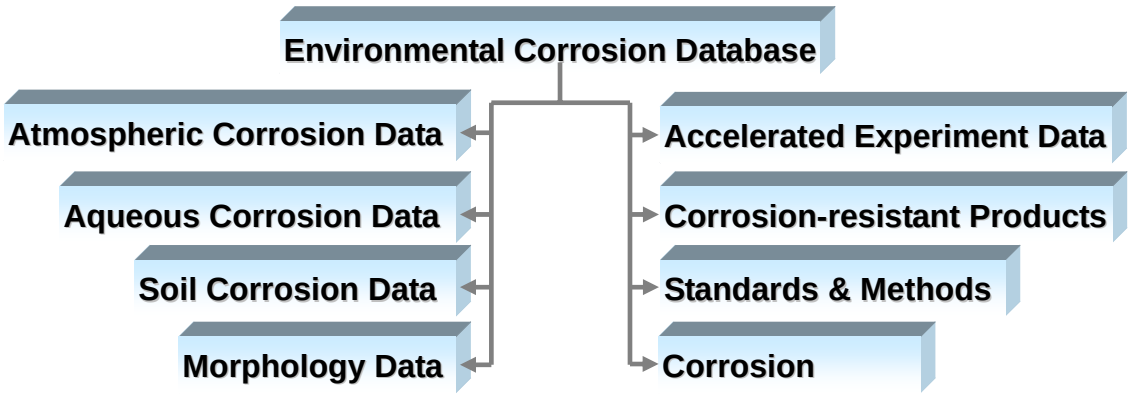

Figure 2. Structure of the database of material environmental corrosion

Table 2. Materials put into tests during 2002 and 2003 financially supported by the Ministry of Science and Technology (Wang, Li, & Luo, 2002)

Network of Test site	General Category	Specific Type	Number of Types	Amount of Samples (piece)
Network of Atmospheric Corrosion Test Sites	Ferrous Metal	Carbon Steel, Low Alloy Steel, Stainless Steel	10	1335
	Nonferrous Metal	Copper, Aluminum, Titanium & Their Alloys	7	801
	Protective Layers	Plated Metallic Layers & Organic Coatings	30	2370
	Construction Material	Construction paint, Water-proof rolling material, Water-proof paint & Concrete	24	2007
	Sum	4 categories	71	6513
Network of Seawater Corrosion Test Sites	Ferrous Metal	Carbon Steel, Low Alloy Steel, & Stainless Steel	10	1515
	Nonferrous metal	copper, Aluminum, Titanium & Their Alloys	8	927
	Plated/Coated Layers	Plated Metallic Layers & Organic Coatings	34	1824
	Structure Parts	Welding Parts & Matching Parts	7	144
	Sum	4 categories	59	4410
Network of Soil Corrosion Test Sites	Ferrous Metal & Organic coating	Carbon Steel (pipe, sheet) & Organic coating	14	1437
	Stainless Steel & Nonferrous Metal	Copper, Aluminum, Lead & Stainless Steel	10	1122
	Concrete	Cement & Concrete	11	384
	Cable and Sleeve Materials	Urban Cables, Rural Cables, Coaxial Cables, Plastic Cable，Bare Lead and Aluminum Painted Steel Belt, Plastic-coated Steel Wire	13	1038
	Sum	4 categories	48	3981
Total Amount			178	14904

The build-up of the corrosion database facilitates the recording and management of data and further enhances the efficiency of data collection and analysis. Initial database approaches were applied to a single computer; therefore they had many limitations, such as a small range of users, simple data service functions, and few applications of data. Because of the different development times for each database, it was necessary to carry out the standardization management for the corrosion data. The present platform for the database software has been transferred from DOS to Windows 9x, and the programming language used includes Foxbase, dbase 2.0, VFP 3.0 etc. The separated nature of the individual databases limited their own application. Therefore, a uniform format of the database and a standardized management system were preconditions for the achievement of the maximum application of the database system. Furthermore, the independent databases must be integrated into one entity, which finally formed an international data-sharing network. That is the way to develop a database system intensively and extensively. In order to realize this purpose, the policy, standards and regulations on data sharing must be established first and the specific funding must be provided for it. In addition, the techniques about data sharing have to be studied simultaneously.

As far as material environmental corrosion is concerned, it has two advantages. Firstly, the data accumulated in the past are a solid basis for the establishment of a data-sharing network. Furthermore, the present experimental sites across China are the guarantee for continuously supplying the “new blood” for the data-sharing network.

3 CONTENTS OF THE DATA-SHARING NETWORK

3.1 Main Purposes

The main purposes include: (1) implementing a data system of material environmental corrosion, which can meet the requirements of China construction and the research demand in the field of material environmental corrosion; (2) accumulating corrosion (aging) data for common construction materials and new materials in typical hostile environments, which can enrich the experimental system of material environmental corrosion, and initiating the accumulation of corrosion data in the typical environments of China western area and the environmental adaptation data of common construction materials.; (3) standardizing the management of the data system of material environmental corrosion and building up the database system, data network and the data application system for it; and (4) constructing a standardization system of the corrosion-resistant and aging-resistant performances of materials as a part of the quality supervision system.

3.2 Working Procedures

The main working procedures contain:
(1) Establishing the policy, regulations, and standards for the data sharing of material environmental corrosion;
(2) Enlarging the corrosion data source (the data collection from the present experimental sites; the integration of the past data of material environmental corrosion; the communication and exchange of internal data);
(3) Processing the data of material environmental corrosion (the data accumulation, inspection, evaluation and processing);
(4) Complementing and renewing the data of material (traditional materials, new materials and varieties of manufactures and construction parts) environmental corrosion;
(5) Building up the general database, based on which the function of data management can be improved and the

research and development of the application software can be carried out;
(6) Studying the principles of material environmental corrosion data and the relation between the principles and environmental factors, further developing the service life forecasting system of material environmental corrosion and the consultation and determination system for corrosion and protection;
(7) Applying the software developed in (6) to the practice environments and scientific research and exchanging it with counterparts;
(8) Constructing the data-sharing network, hardware and network database and developing the relevant management and consultation software;
(9) Maintaining and managing all of the systems; and
(10) Realizing the data standardization management of material environmental corrosion.

4 STRUCTURE OF THE DATA SHARING NETWORK

Newly developed computer technology provides the possibility of data sharing through the Internet for users. The structure of the database system in this network is B/S structure. Users can browse and perform all functions through Internet browser. The description system contains the following sections: the hardware and software used in the system, the design of the system structure, the database design, and the construction of the data-sharing network for material environmental corrosion.

4.1 Hardware and Software

Server：Dell poweredge 2850
Operating system: Linux redhat
Database system：Oracle server
Application software server：IBM Websphere application server
Programming language：JAVA

4.2 Design of System Structure

B/S structure was applied to the design of the website. The system mainly includes the following modules:
(1) Registration and login module;
(2) User, authorities and role management module;
(3) User message module;
(4) News management module;
(5) Data query module
(6) Data management module: realizing the long-distance web management of data;
(7) Data transaction module: transforming Excel data file to Oracle data file and define Excel data template; and
(8) Other log management modules.

4.3 Database Design

Oracle9i is the most popular database management system in the world (Tan, Wang, & Zhao, 2002). The advantage of it lies in its operating stability and safety and its capability for supporting huge databases. Also, it

can be simply used as an Internet database management platform with high safety. Therefore, the database of material environmental corrosion has been constructed with Oracle9i, which has some characteristics in common with other corrosion databases, such as material properties, environmental factors, corrosion status, and data source (Anderson, 1988). Specifically,

1. Material properties: consisting of material name, brand, specimen number, heat treatment status, appearance, size, weight, chemical composition and mechanical properties.
2. Environmental factors: consisting of experimental site name, time, temperature, humidity, meteorology factors, corrosion medium and pollutant.
3. Corrosion status: consisting of corrosion type, corrosion area, corrosion intensity, weight loss, corrosion rate, the maximum pitting depth and strain stress status.
4. Data source: consisting of data from each experimental site, data collection, analysis report, corrosion experiment criterion and standard, journal paper.

The present data-sharing network contains data on a large number of specimens relating to many kinds of materials, various testing sites and different sampling periods. Therefore there will be complicated effects resulting from the combination of these factors. Considering the situation, the design of the database structure adopted an object-oriented, relational dynamic database system, in which the data are classified into different data types and fields. By this means, the management of data can be accomplished together and the query and search speed can be improved. Moreover, in order to meet the requirement of customers, the database includes an abstract database of scientific papers, academic reports and other references.

5 SYSTEM COMPOSITION AND REALIZATION

The database system for the network of material environmental corrosion is composed of four basic systems: database management system, database query system, database analysis system and data-sharing platform (data-sharing network).

5.1 Data-sharing Platform

The national data-sharing network of material environmental corrosion is the physical platform for collecting and sharing the data and relevant information of material environmental corrosion. It can provide a service for quick querying, searching and downloading data. Also, a user with administrator authority can perform the database management, such adding, deleting and revising data.

5.2 Database Query System

With the aid of the database query system, a user can query (1) the chemical composition and mechanical properties of materials; (2) corrosion data of materials in atmospheric, seawater and soil environments; and (3) meteorological data and environmental corrosion data. The query patterns include point query, line query and plane query. Users can obtain the desired data simply by use of any combination of these patterns.

5.3 Database Management System

In this system, an administrator can perform management operations, such as adding data, deleting data, saving the revised data and canceling the former operation, as well as updating the database. By these operations, the

completeness of database can be ensured.

5.4 Data Analysis System

In the following section, regression analysis and the environmental synthetic factors model are used to forecast atmospheric corrosion of ferrous metals. With the application of graphical display classes in Java, various graphs and tables, including volume graphs, curves and pie graphs, can be shown. With the display function, the variation rules of the data can be achieved straightforwardly. Moreover, through the database query system and the database management system, users can obtain the analyzed results, such as the coefficients of models, graphs/tables generated from data, etc.

5.5 System Implementation

The web database of material environmental corrosion can be maintained through the network database management system and query system. Therefore the data of material environmental corrosion can be shared intensively. Users of the web database of material environmental corrosion can be divided into a common group and an admin group. Common users can query data, such as material properties, material corrosion status, the meteorological and environmental information of experimental sites etc, from the database. However, they have no permission to do administration operations, including adding, deleting, updating and etc, to the database. The admin users have more privileges and are allowed to do both query operation and other data management operations. Consequently, they can easily collect data from labs all over the country.

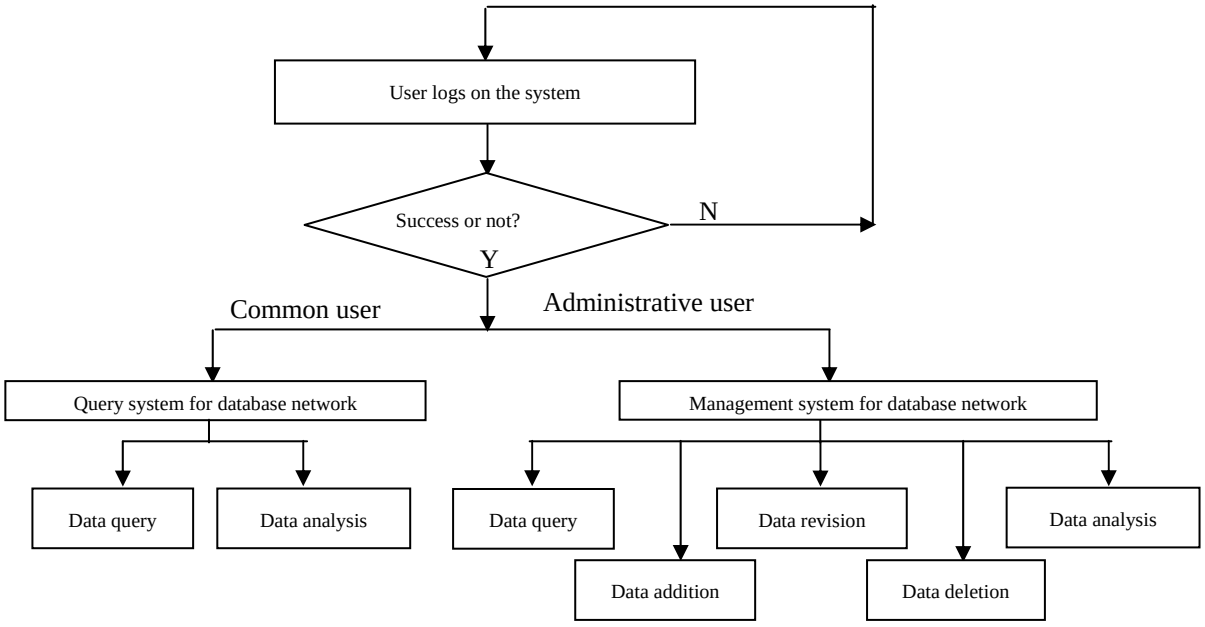

Figure 2. Functional Architecture of the Network Database Sharing System

Taking data query as an example. After the user logs on from the browser (IE Explorer) and submits the query form, the browser will send the query back to the application server (Websphere). Then, the server-side JSP program will run. It gets the information sent from the browser, assembles this information into some DML query command, such as SELECT query, and sends it to the database server (Oracle 9i). The database server

executes those commands, retrieves the requested data, and returns the results back to the application server. Then, the server-side JSP program carries out sorting, grouping, and formatting on the data and outputs them to the browser. At last, the data are put into a table/graph format, which are also page-segmented and printer ready, and are displayed in the browser. The whole query procedure is figured out in Figure 3.

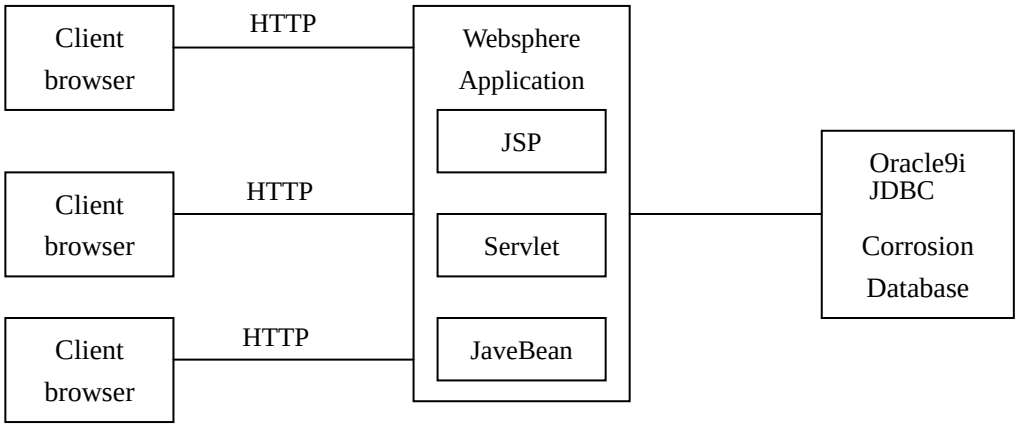

Figure 3. Sketch of the query procedure

The following example details the web-query procedures:
(1) Entering the database query webpage and selecting an atmospheric corrosion item and going to the following webpage (Figure 4);
(2) In this webpage, the mixed query can be performed according to the brand number, volume number and experimental sites of the materials. In addition, the download of an Excel file for the queried data can be carried out with the permission of the authority. Furthermore, the data can be analyzed simply, as shown in the following figure (Figure 5);
(3) After selecting sites, experiment time, material types and figure types, the comparative analysis can be performed, as shown in Figure (Figures 6 and 7).

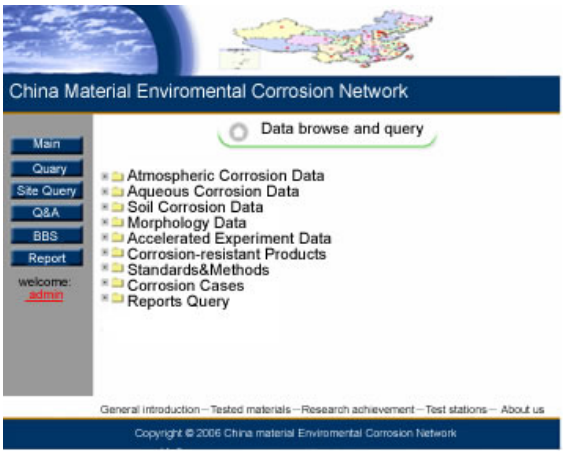

Figure 4. The webpage for a database query

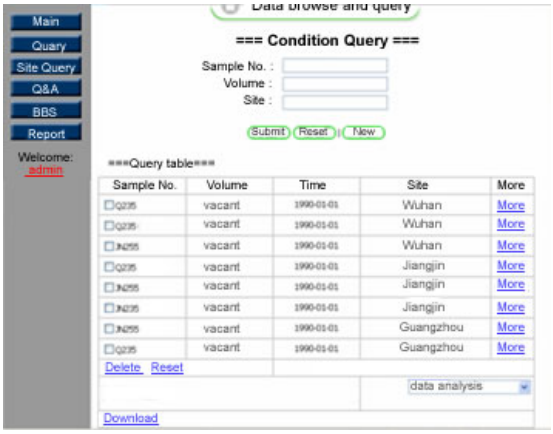

Figure 5. The webpage for the data query with various query patterns

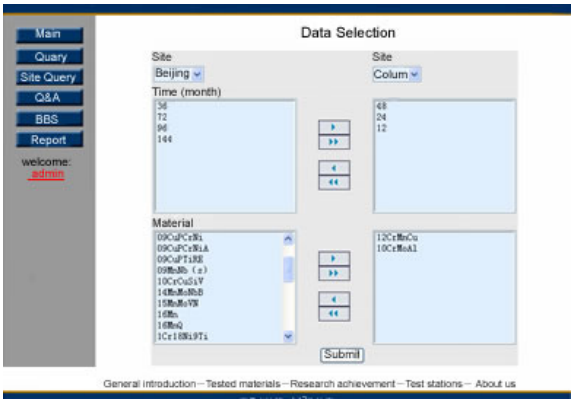

Figure 6. The webpage for selecting the analysis conditions

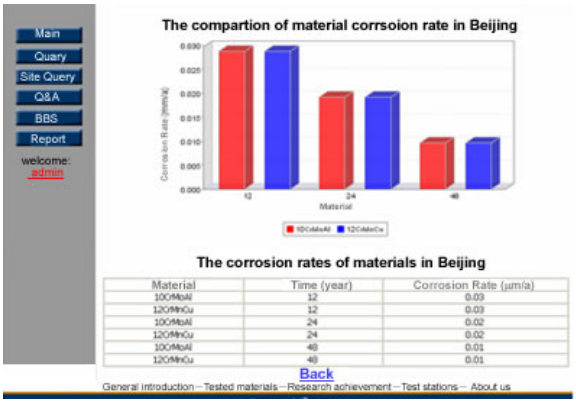

Figure 7. The webpage showing the analysis result with volume graph

6 CONCLUSIONS

Written in Java language and based on Oracle database technology, the network of data sharing of material environmental corrosion and the corrosion database management system have been developed on the basis of long-period corrosion failure data. These accumulated data are of two types. One is data for different materials in the typical environments (atmosphere, seawater, and soil). The other is corrosion data in production environments, provided by a variety of firms. This network system enables standardized management of

environmental corrosion data, an effective data sharing process, and research and development capabilities for new products and after-sale services. Moreover this network system provides a firm base and data-service platform for the evaluation of project bids, safety and service life.

7 PROBLEMS IN FUTURE APPLCATIONS

During the construction of the network of data-sharing of material environmental corrosion, some problems were encountered, as shown by the following:

7.1 The evaluation of material environmental corrosion data

Data are fundamental to the database. The reliability, precision and repeatability of data are significant factors in the quality evaluation of the database. Therefore, it is necessary to establish a professional technical committee, by which the evaluation criteria and standards can be developed based on the progress of fundamental theories. In most cases, experimental data must be analyzed following the characteristics of the corresponding subject areas. In this way, the judgments made will be more correct, based on which the further analysis can explore the principles behind the phenomena or data. The data of material environmental corrosion are related to a huge systematic data cluster and associated with many influencing factors. Therefore, to establish the evaluation criteria and standards in different environments is a problem to be solved.

7.2 Sharing mode for different users

In the data-sharing network, various kinds of users were defined, who have different levels of sharing authorities for the data. Basically, there are three types, limitless sharing, sharing with limits and sharing with payment. The multi-level sharing system can be realized by defining users' authorities with different user names and passwords. The data of material environmental corrosion have been accumulated with much financial input and labor input, therefore the security of the data and how to provide the sharing service with different modes are the vital problems at present.

7.3 Sharing compensation for the data from other sources

In order to enlarge the data source, data of material environmental corrosion have to be collected from other industrial departments. Therefore, it is necessary to constitute some regulation and policy on data compensation for those departments who supply data to this data-sharing network. A method was put forward, in which the data-providing departments can share the other data in the network. Another problem is the collection of the scattered data, which is distributed in journals, published reports and papers.

7.4 Protection of the intellectual property of data

The online data-sharing is definitely associated with the security of data. Therefore how to protect the intellectual property of the data by the setup of the operating system and database system is a vital problem to be solved.

8 ACKNOWLEDGEMENT

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