Contemporary problems of Architecture and Construction

Proceedings of 7th International Conference
Contemporary Problems of Architecture and Construction
Florence - Italy

La scuola di Pitagora editrice

UNIVERSITÀ DEGLI STUDI FIRENZE
DIDA DIPARTIMENTO DI ARCHITETTURA

Edited by
Stefano Bertocci
Paola Puma

Fabbrica della Conoscenza

Collana fondata e diretta da Carmine Gambardella

numero cinquantotto

Contemporary problems
of Architecture and Construction

Edited by
Stefano Bertocci
Paola Puma

Progetto grafico: Lorenzo Cantini

Impaginazione: Matteo Pasquini

Via Monte di Dio, 54
80132 Napoli
Telefono e fax +39 081 7646814
www.scuoladipitagora.it
info@scuoladipitagora.it

ISBN 978-88-6542-431-5 (versione cartacea)
ISBN 978-88-6542-443-8 (versione elettronica nel formato PDF)

Il volume è stato inserito nella collana Fabbrica della Conoscenza, fondata e diretta da Carmine Gambardella, in seguito a peer review anonimo da parte di due membri del Comitato Scientifico.
The volume has been included in the series Fabbrica della Conoscenza, founded and directed by Carmine Gambardella, after an anonymous peer-review by two members of the Scientific Committee.

Contemporary problems of Architecture and Construction

Selected, blind peer reviewed papers from
7th International Conference on Contemporary Problems of Architecture and Construction
November 19th-21st, 2015, Florence - Italy

Edited by
Stefano Bertocci
Paola Puma

La scuola di Pitagora editrice

UNIVERSITÀ DEGLI STUDI FIRENZE

Board of the universities and partner

- University of Florence, Italy
- National University of Architecture and Construction of Armenia, Armenia
- Beijing University of Civil Engineering and Architecture, China
- Czestochowa University of Technology, Poland
- St. Petersburg State University of Architecture and Civil Engineering, Russia
- VSB-Technical University of Ostrava, Czech Republic
- Fondazione Romualdo Del Bianco - Life Beyond Tourism, Italy

In collaboration with

Centro Congressi al Duomo

Vivafirenze.it

Committees

Honorary Committee

Prof. Luigi Dei, Rector of University of Florence, Italy
Prof. Gagik Galstyan, Rector of National University of Architecture and Construction of Armenia, Armenia
Prof. Zhu Guang, Rector of Beijing University of Civil Engineering and Construction, China
Prof. Ivo Vondrák, CSc. Rector of VSB - Technical University of Ostrava, Czech Republic
Prof. Maria Nowicka-Skowron, Rector of Czestochowa University of Technology, Poland
Prof. Yevgeniy Ivanovich Rybnov, Rector of St. Petersburg State University of Architecture and Civil Engineering -SPSUACE, Russia
Paolo Del Bianco, President of Fondazione Romualdo Del Bianco-Life Beyond Tourism, Italy

International Scientific Committee

ITALY
Prof. Marco Bellandi, Department of Economic Sciences and Management, University of Florence
Prof. Saverio Mecca, Dean of the Department of Architecture, University of Florence
Prof. Maria Teresa Bartoli, Department of Architecture, University of Florence
Prof. Phd. Stefano Bertocci, Department of Architecture, University of Florence
Prof. Marco Bini, Department of Architecture, University of Florence
Prof. Phd. Paola Puma, Department of Architecture, University of Florence
Prof. Emma Mandelli, International Institute Life Beyond Tourism

ARMENIA
Prof. Gagik Galstyan, Rector of National University of Architecture and Construction of Armenia
Prof. Arkadi Barkhudaryan, Vice rector for Academic affairs of National University of Architecture and Construction of Armenia
Prof. Yuri Safaryan, Vice rector for Scientific affairs of National University of Architecture and Construction of Armenia
Prof. Vardges Yedoyan, Vice rector for International relations of National University of Architecture and Construction of Armenia
Prof. Suren Mkhitaryan, Head of Chair of Higher Mathematics of National University of Architecture and Construction of Armenia

CHINA
Prof. Zhu Guang, Rector of Beijing University of Civil Engineering and Construction
Prof. Song Guohua, Vice rector for Scientific research and foreign exchange, Zhejiang University
Prof. Msc. Chengzhi Qi, Beijing University of Civil Engineering and Architecture
Prof. Liu Linan, Dean of Architecture School, Beijing University of Civil Engineering and Architecture
Prof. Qi Jilin, Chair professor, School of Civil and Transportation Engineering, Beijing University of Civil Engineering and Architecture

CZECH REPUBLIC
Prof. Darja Kubeckova Msc., Vice rector for development and investement construction, Phd. VSB -Technical University of Ostrava
Assoc. Prof. Milos Kalousek, Msc. Ph.D. Brno University of Technology
Prof. Msc. Csc. Alois Materna, MBA, Civil Chamber of the Czech Republic

GEORGIA
Prof. Arch. Nana Iashvili, Tbilisi State Academy of Art

POLAND
Prof. Msc. Lucjan Kurzak, Czestochowa University of Technology
Prof. Msc. Jaroslaw Rajczyk, Czestochowa University of Technology
Prof. nzw. Dr. hab. inz. Marlena Rajczyk Czestochowa University of Technology

RUSSIA
Prof. Yevgeniy Ivanovich Rybnov, Rector, SPSUACE
Prof. D.Sc. Evgeny Borisovich Smirnov, Pro-rector for R&D, SPSUACE
Prof. D.Sc. Sergey Vladimirovich Sementsov, Dean of Faculty of Architecture, SPSUACE
Prof. D.Sc. Tamara Aleksandrovna Datzyuk, Head of the chair of building physics and chemistry, SPSUACE
Prof. D.Sc. Lidia N. Kondratyeva, Head of the chair of structural engineering, SPSUACE

Organizing Committee

ITALY
Prof. Maria Teresa Bartoli, University of Florence
Prof. Phd. Stefano Bertocci, University of Florence
Prof. Phd. Paola Puma, University of Florence
Prof. Emma Mandelli, International Institute Life Beyond Tourism
Simone Giometti, Fondazione Romualdo Del Bianco-Life Beyond Tourism
Michaela Zackova, Life Beyond Tourism

ARMENIA
Prof. Gagik Galstyan, National University of Architecture and Construction of Armenia
Prof. Doctor Yeghiazar Vardanyan, National University of Architecture and Construction of Armenia
Prof. Yuri Safaryan, National University of Architecture and Construction of Armenia
Prof. Vardges Yedoyan, National University of Architecture and Construction of Armenia
Irina Igitkhanyan, National University of Architecture and Construction of Armenia

CHINA
Prof. Chengzhi Qi, Msc. Beijing University of Civil Engineering and Architecture

CZECH REPUBLIC
Prof. Darja Kubeckova Msc. Phd, VSB -Technical University of Ostrava

POLAND
Prof. Lucjan Kurzak Msc, Czestochowa University of Technology

RUSSIA
Prof. D.Sc. Evgeny Borisovich Smirnov, SPSUACE

Organizing Secretary

Stefania Macrì, Life Beyond Tourism

GREETINGS BY THE UNIVERSITY OF FLORENCE DEPARTMENT OF ARCHITECTURE/DiDA

Saverio Mecca
Director of the Department of Architecture
University of Florence, Italy

I am honoured to present in Florence this book that collects contributions for multiple experiences of international research on the topic of Contemporary problems of Architecture and Construction, particularly complex and articulated.
The management of the contemporary aspects and problems of historical heritage, the preservation of cultural memory, are necessary activities that concern and cut across a variety of different disciplines, whose complexities are evident as long as they require a specific definition of the identity of the architecture.

7th International Conference
Contemporary Problems of Architecture and Construction
Florence, 2015

The Department of Architecture DIDA is a structure of the University of Florence dedicated to scientific research, educational and formative activities, transfer of knowledge, innovations of the activities addressed to architecture, industrial design, territorial and landscape planning.
The Department of Architecture promotes the internationalization of the research activities, of the valorisation and transfer activities, of the scientific and technological advice, even in cooperation with other academic and research structures, both public and private, as it is underlined in the book that we are presenting.
The DIDA, looking forward to these aims, organized an internal system of laboratories by instituting the DIDALABS. The mission of the DIDALABS is to support, both scientifically and technically, the education, the research and the higher formation, the transfer of knowledge of the DIDA and of the Athenaeum in the areas of architecture, industrial design and landscape and territorial planning area.
Above all, the Survey of the Architecture Laboratory LRA is our structure predisposed to the formation and research above the Architectural and Archaeological Heritage. It produces surveys of the architectural, the urban and landscape complex integrating the competences that are now being employed in the sectors of documentation and preservation of the Heritage.
These activities may also support the public and private institutions operating in the sector of Cultural Heritage.
The knowledge transfer represents the fundamental element, which can valorize or potentiate the formative offer through the conducted scientific experiences.
In addition, these experiences permit to tune the operative methodologies for the digital survey, giving essential instruments in order to understand and evaluate the preservation and restoration interventions.
The activities developed by the laboratory include several examples of case studies relating to UNESCO sites, investigated with the architectural survey and the Science of Representation, explicating in these pages the technological development that has focused on the representation of architecture during the recent years outlining paths of inquiry through which to define methodologies and operational protocols for the understanding of the historical and monumental complex.

The research presented often involve students, graduate students or PhD students, increasing the value of the experience with that of advanced training and education in a sector in which knowledge can be developed only staying in contact with the architectural and engineering contemporary problems.
I believe that the occasion of this International Conference, which presents a full program of roundtables and meetings, represents an important opportunity for dialogue and scientific exchange on the subject, being able to offer excellent points of reflection for teachers, professionals and students under an international point of view to the historical heritage.
Know in depth a building, especially when its historical and cultural value is strongly established, as in some cases that will be presented here in this volume, is the basis for the preparation of a conservation project that will necessarily be caught and not just aimed at the preservation but aiming too its transformation so that it can be revived and returned to the community.
I believe that all phases of the survey and analysis of a monumental property without hesitation could be define purely an “architectural project”.
Finally, our warm thank you to the organizers and members of the research groups that have helped to enrich their experiences and reflections with the issues of the Conference.

Stefano Bertocci, Paola Puma
The scientific referees for University of Florence, Department of Architecture-DiDA

A short history of the International Conference on Contemporary Problems of Architecture and Construction

To present the 2015 edition, we should like to premise a short history of the conference: in 2008 and 2010 Yerevan State University of Architecture and Construction has organized the first and the second International Conference entitled “Architecture and Construction - Actual Problems”.
The conference was held in Jermuk, Armenia. The third year was organized in collaboration with the Beijing University of Civil Engineering and Construction from October 20th to 24th, 2011, and was entitled “International Conference on Contemporary Problems in Architecture and Construction” and this title is used up to the present day.
The fourth conference was held in Czestochowa (Poland) from September 24th to 27th, 2012, as a joint effort of the Yerevan State University of Architecture, the Beijing University of Civil Engineering and Construction and the Czestochowa University of Technology.
The fifth conference was organized by the Saint Petersburg University of Architecture and Construction from June 25th to 28th, 2013, as a joint effort of the Yerevan State University of Architecture, the Beijing University of Civil Engineering and Construction, the Czestochowa University of Technology and Saint Petersburg University of Architecture and Construction.
The sixth conference edition was organized by the VŠB - Technical University of Ostrava (Czech Republic) from June 24th to 27th, 2014, jointly with the Yerevan State University of Architecture, the Beijing University of Civil Engineering and Construction, the Czestochowa University of Technology and Saint Petersburg University of Architecture and Construction.

The 7th International Conference on Contemporary Problems of Architecture and Construction

The “7th International Conference on Contemporary Problems of Architecture and Construction” we are proud to guest in Florence, is held in 2015 at University of Florence, organized by the Department of Architecture-DiDA on 19th -21th November, 2015, with the collaboration of the others universities and entities involved in the partnership.
The 7th Conference is promoted by six different universities, all represented by some of their members in the Scientific Committee:
- University of Florence, Italy
- National University of Architecture and Construction of Armenia, Armenia
- Beijing University of Civil Engineering and Architecture, China
- University of Technology Czestochowa, Poland
- St. Petersburg State University of Architecture and Civil Engineering, Russia
- VSB - Technical University of Ostrava, Czech Republic.

The Fondazione Romualdo Del Bianco with its International Institute Life Beyond Tourism, who has been essential in facilitating at early stage the contact between University Florence and the other Promoters, has had an essential role in to the dissemination of the conference throughout its international network of universities and the organizing managing.

This edition of the conference is an interdisciplinary symposium dedicated to the architectural and urban works -from the 2nd half of 20th century- and to urbanism with a special focusing on topics of “cultural heritage’s culture”.
The intention of the organizers is, in fact, continuing the discussion on the relationship between the society and the technical and cultural meanings of architecture and urbanism. Also representatives of other fields than architecture have had the opportunity to submit contributions and open the space for the discussion of other problems.
The purpose of the conference is to find and evaluate in the open discussion the current state of knowledge of architecture (see at topic 1. Civil Engineering, reconstruction, sustainable construction, materials and technologies and topic 2. Architecture and Design, urban planning, urbanism) not only from the perspective of different scientific fields but from the experience from various countries with their different developments and approaches (see at topic 3. Environmental engineering, energy, green buildings).
Besides the technical and infrastructural dimensions of the construction (see at topic 4. Geotechnics, seismicity hazard analysis and prevention and topic 5. Construction, structural mechanics, transport problems), we focused on one of the largest fields of specialization of the Italian competence: the culture of heritage (see at topic 6.Technologies and operational methodologies for conservation and topic 7. The fruition of the heritage: cultural value-based travel, routes and landscape. New uses and enhancement of monuments).
The issue is addressed from many points of view: from the methodologies of documentation and survey to the protection theory and practice.
Finally, the highlights of the Florentine edition: the most recent new lines of research regarding the fruition of heritage and its enhancement in its many different meanings.

FONDAZIONE ROMUALDO DEL BIANCO®

Life Beyond Tourism®

Learning Communities for

Intercultural Dialogue

Helping to Promote the 2003, 2005 UNESCO Conventions
with the 1972 UNESCO Convention
by Fondazione Romualdo Del Bianco®

LIFE BEYOND TOURISM®

GREETINGS BY THE FONDAZIONE ROMUALDO DEL BIANCO-LIFE BEYOND TOURISM

Paolo Del Bianco
President of the Fondazione Romualdo Del Bianco-Life Beyond Tourism
Florence, Italy

Dear Participants in the 7th International Conference on Contemporary Problems of Architecture and Construction,

the Foundation, myself and our collaborators are happy to have been able to work in conjunction with the universities represented in the International Scientific Committee for the organization of the 7th International Conference on Contemporary Problems of Architecture and Construction, the first edition in Florence. So – on behalf of the Foundation – I would like to welcome to Florence and to our headquarters conference rooms all those from 49 universities and institutes from 19 countries who have contributed with their papers and presence to the success of the initiative.

Please allow me a special thanks to the National University of Architecture and Construction of Armenia in the person of the Rector Prof. Gagik Galstyan and Pro Rector Vardgues Yedoyan, who proposed us last year to collaborate for a Florentine edition of the conference. Also thanks to the staff of the Florence University that supported the initiative since the beginning with their expertise and availability.

The Fondazione Romualdo Del Bianco-Life Beyond Tourism was initiated after the fall of the Berlin Wall as a result of an idea that came to me, at that time I was a hotelier and businessman, to favor in Florence mutual familiarity and knowledge among young university students from the countries of central and eastern Europe and Western ones. The goal was to unite them by means of architecture, art and culture and Florence was a place where they could have the opportunity to meet, sharing knowledge and experiences, improve their human and cognitive skills. Therefore, since 1996 the Foundation has always based its activities on such crucial factors as: Travel, Youth, Interculturalism, Cultural Heritage, Dialogue, Knowledge and Respect for Diversity. Firmly believing in the importance of all this, the Fondazione has sought over the past few years to make a systematic contribution to this form of rapprochement, and so its network has grown year by year, moving ever further eastwards, thanks to these youngsters: over 200,000 study days in Florence to foster encounters devoted to study and research among young people from all over the world, over 500 institutions and universities from 80 countries of the five continents have bonded together to form the Foundation’s international network.

Cultural and architectural heritage provides a strong motivation for bringing young people together, thus in the Fondazione it is not seen as an end in itself but as a tool for the achievement of our mission. This may seem like an odd way of interpreting art and architectural heritage, but our aim is to foster opportunities for interpersonal acquaintance among different cultures, thus forging relationships which, while maybe not always based on mutual understanding, lead at least to an appreciation of diversity, thus to esteem and possibly even to friendship.

Over the years the Fondazione’s activities thus gave a new meaning to the word hospitality, which in my capacity as a hotelier I had never associated with the feelings that these young people experienced, almost to the point of tears, before their departure from Florence. From that moment on, I set out on a new path linking the concept of hospitality to feelings, and feelings to personal commitment, in order to foster opportunities for intercultural dialogue, thus making my contribution to Peace. I perceived a new mission for the art of hotel hospitality and began to experience a certain revulsion for the word “tourism” inasmuch as it is universally associated with consumer-related services, creature comforts and so on, but not with hospitality, not with hospitality from the heart. If we truly understand travel to be an exercise in meeting, knowing, communicating, appreciating and respecting cultural diversity, then we have to forgot using the word “tourism”. The Fondazione, too, has increasingly focused its attention on heritage as a fantastically strategic factor in its mission.

While not ourselves scholars yet still playing a role in the service industry for the huge masses of people who travel to admire our cultural and architectural heritage, we began to ask ourselves questions to which we sought answers, especially in connection with how the use and enjoyment of cultural and architectural heritage could help in building lasting peace among peoples. Around tangible and intangible cultural and architectural heritage people meet, they ask questions, they dialogue, they get to know each other, they gain an appreciation for cultural diversity, they get their bearings and they get used to showing respect for that diversity, even if they cannot get a real insight into its deeper aspects and scope.
If we are able in translating the work of architecture or art into a work produced by mankind and setting it in its broader (especially socio-historical) context, comparing it with coeval works in other countries; if we educate the broad masses to appreciate the overall context in which a work of architecture or art was conceived, commissioned, funded and ultimately made to a given design and with given materials for a given function, and then compare that context with the context of other countries and other religions, then it becomes a far easier task to bring those masses closer to cultural and architectural heritage and to get them involved with it. In fact it could even become a “consumer product” effective in fostering intercultural dialogue. This, because mass tourism is not stupid by definition, it becomes stupid if it is treated stupidly.

That is the belief that inspired the Fondazione to develop a philosophy which it has christened Life Beyond Tourism, an operational practice designed to offer a virtual platform to intercultural knowledge through heritage.

All of this may be traced back the fact that the event, the work of architecture or art, the context, in fact everything comes together to foster the conditions for an emotion which is crucial, when combined with knowledge, for understanding the deeper significance of a work of art and for penetrating the spirituality (in the sense of man’s unending search for the meaning of life and the universe) of the culture that produced it. Thus architecture, art and culture are seen also as a crucial opportunity for dialogue because it can prompt us to see in every human being the selfsame questioning astonishment that we all share.

At a second stage, the Foundation, with the participation of all the members, has arrived to further translate the philosophy in the Life Beyond Tourism Model, with the Manual for its practical application on the territories and its Certification to measure the results into the terms of Intercultural Dialogue.
A Memorandum of Understanding was signed with ICOMOS 2013, March the 4th, and consequently the Model was applied in Florence during the 18th ICOMOS General Assembly (November 2104); with <vivafirenze.it>, the Model was able to give its own economic support to the General Assembly itself.. Finally, the resolution n° 42/2014 of the 18th ICOMOS General Assembly the ICOMOS institutional recognition and support for a worldwide dissemination was recognized.

To understand the level of interest that Life Beyond Tourism found - right now- in the faculties of Tourism, we add with pleasure that the first week of this September 2015, in Japan in Tokyo, at the Josai International University (JIU), intensive academic courses on the philosophy Life Beyond Tourism and its Model have started for its practical application with Quality Certification.
The intensive course was one-week duration and it will be any semester weekly intensive course. The Docent was Visiting Professor Arch. Corinna Del Bianco. The connection between the Foundation and the Josai International University was established thanks to Prof. Masanori Aoyaghi from Tokyo University, currently Commissioner of the Agency of Cultural Affairs in Japan.
The next seminar will take place in Tokyo at the Toyo University next October 2015. Any educational or training institution interested in including in its teaching programs the subject of a new sustainable development strategy for the territories and their cultural (architectural) heritage, for developing tourist economy are invited to apply the Foundation.

In pursuing our mission, we have always placed man's activity at the very heart of our work, viewing it as an admirable construction within the created world, capable of being proactive, of seizing opportunities such as those that now, for all their intrinsic difficulties, offer themselves to us in this newly globalised world. Based precisely on all of these young people from different countries, our driving aim has been to use practice to forge the experience of getting to know one another, working together to express shared concepts, to bring them to fruition in the harmony of an environment extraneous to all those taking part yet, at the same time, common to all of them inasmuch as it is part and parcel of our common world heritage.

This is the program by which Romualdo Del Bianco Foundation intends to gather the enthusiasm, the adhesion, the participation of those who see architecture, art and culture not only as an universal expression of beauty, elegance and refinement, but also as a powerful mean to contribute to the development of the intercultural dialogue. You, your colleagues and students are welcome in joining us.

TABLE OF CONTENTS

SESSION 1
Civil engineering, reconstruction, sustainable construction, materials and technologies

SESSION 3
Environmental engineering, energy, green buildings

SESSION 4
Geotechnics, seismicity hazard analysis and prevention

SESSION 5

Construction, structural mechanics, transport problems

SESSION 7
The fruition of the heritage: cultural value-based travel, routes and landscape/New uses and enhancement of monuments

SESSION 1

CIVIL ENGINEERING, RECONSTRUCTION,
SUSTAINABLE CONSTRUCTION,
MATERIALS AND TECHNOLOGIES

APPLICATION OF THE HYDRODYNAMIC LEVELING METHOD IN ERECTION WORK

Arkadi Barkhudaryan[1], Misak Barkhudaryan [2]
National University of Architecture and Construction of Armenia, Armenia
email: [1]arkadi.barkhudaryan@yahoo.com, [2] misak.barkhudaryan@gmail.com

Keywords

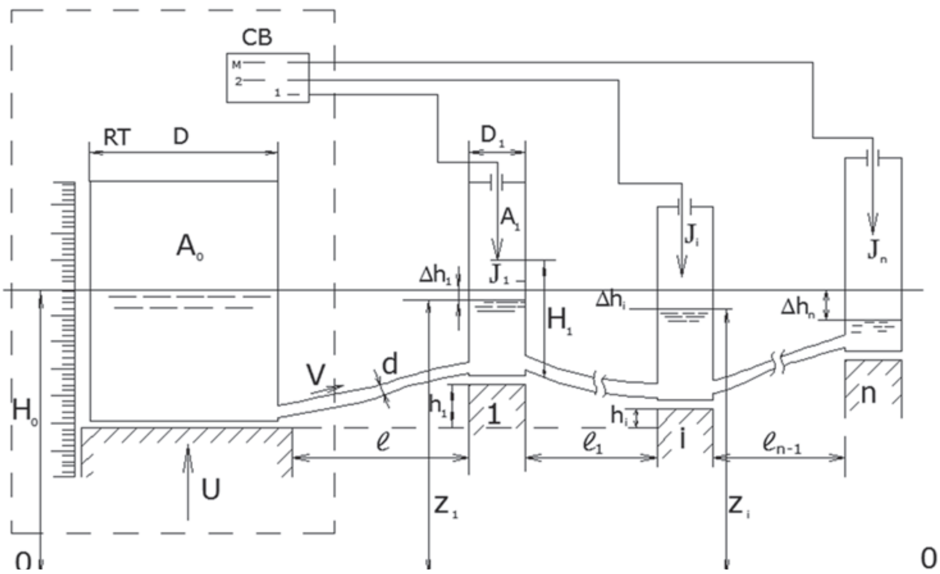
hydrodynamic leveling, observation, providing

ABSTRACT

The advancement of technical progress pose problems before engineers and researchers to automate some production processes. Design and creation of new systems of automatic control bring research problems of time-varying processes in the forefront.
Hydroleveling is used in building of unique structures and erecting large-size processing equipment.
It applies equally to construction of high-rise structures, linear and annular accelerators, radioactive instrumentation and radar telescopes, automatic production lines, assembly belt lines, high-head dams, special overhead covers etc. Experience of operation of various structures has shown that necessity of carrying out precise leveling often arises during their operation.
This study aimed at carrying out observations of objects under operation enables determining of structures sinking values and obtaining regularities of their increase so that at a later date predict expected sinking and take in time measures for preventing emergency state of structures. This paper presents possibility of application of hydrodynamic leveling technique in erection work. Such researches are grounded usage of the method and providing precise measurement while erecting special equipment.

1. INTRODUCTION

In mounting of special structures or heavy-duty equipment it is necessary to carry out geodetic support with the purpose of their installation in designed position to an accuracy of 0.1mm. Until now to these ends a method of hydrostatic leveling have been applied (Vasiutinski. I.Yu. 1976).
Now let us consider the possibility of usage of the hydrodynamic leveling (Movsesyan R.A., Barkhudaryan A.M. 1976) technique for determining the difference, while performing erecting work, between heights of two points where transducers are attached. Fig.1 shows the diagram of the hydrodynamic leveling system.
In mounting of a special equipment often necessary to install two or more slabs in one horizon. toward this end it is possible to employ open-loop (fig.2) system or close-loop (fig.3) system of hydrodynamic leveling.



1) Principal diagram of the hydrodynamic leveling

2. THE MAIN CONCEPT

Let us assume that the slab I is in level position and it is necessary to bring the slab II in the same horizontal plane. Control-measuring vessels (transducers) 1 and 5 are installed on the I slab, control-measuring vessels 2,3, and 4 – on the II slab.

For each specific system installation time t_0 of steady motion of the fluid in the system is determined theoretically or experimentally.

Parameters of the system is selected in such a way that in measuring the high position contact of the liquid and any point of the signaling device occurred after steady motion is set up.

As opposed to the current system of hydrodynamic leveling, on a hoister a two-sectional regulating tank is installed (fig.4). The regulating tank in its interior by a vertical partition is divided in two independent sections of A_0' and A_0'' areas, respectively, as shown in fig. 4. Fluid of one section is communicated with the main system through a manifold equipped with a valve.

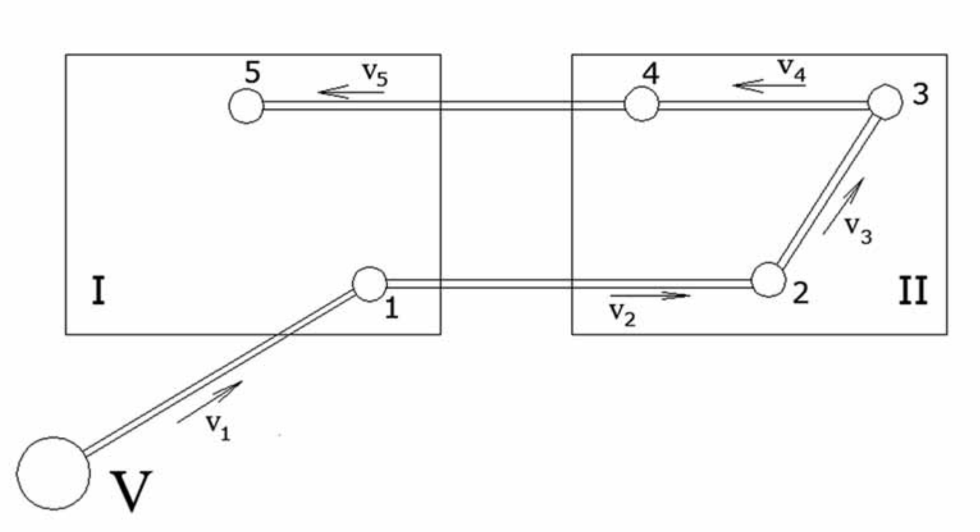
Measurements are carried out in two phases. In the first one the regulating tank is lifted with open K valve, in that the fluid's level change in measuring heads occurs due to volume change of fluid in both the first and the second sections of the regulating tank.

Fluid travel in measuring heads till its contact with the signaling devices is regulated by functioning of meters in corresponding canals.

When reading is coming to an end readings of corresponding meters $N_1', N_2', N_3', N_4', N_5'$ are taken.

The regulating tank is brought to its initial position. After equilibrium state of fluid is setup the valve K is closed and the second phase of measurements is proceeded. Similarly in the second phase readings of meters $N_1'', N_2'', N_3'', N_4'', N_5''$ are taken.

Having known readings of meters of two phases of measurements, by corresponding formulas differences of levels of points 2,3, and 4 relative to 1 and 5 control points are determined.



2) Open-loop system

3. OPEN-LOOP SYSTEM OF HYDRODYNAMIC LEVELING

1. Suppose the hydrodynamic leveling system is in open-loop state (fig.2). In the first state, when the regulating tank with the valve open and after steady motion is established, the rate of rising of the fluid level in the system is determined by the formula

$$u_{cm}' = \frac{\left(A_0' + A_0''\right)u}{A_0' + A_0'' + 5A} = c_1 u \,, \tag{1}$$

where u is the velocity of lifting the regulating tank; A is the area of the free surface of the fluid in the measuring head vessel.

Average velocities of fluid's travel over separate sections are

$$\mathrm{v}_1' = 5c_1 u \frac{A}{\omega};$$
$$\ldots$$
$$\mathrm{v}_\mathrm{i}' = (6-i)c_1 u \frac{A}{\omega}; \qquad (i = 2;3;4) \tag{2}$$
$$\ldots$$
$$\mathrm{v}_5' = c_1 u \frac{A}{\omega}.$$

2. In the second phase, when the regulating tank with the valve closed, velocities of moving liquid are determined by the following formulas

$$u''_{\mathit{cm}} = \frac{A_0'}{A_0' + 5A} u = c_2 u, \tag{3}$$

$$\mathrm{v}_1'' = 5c_2 u \frac{A}{\omega};$$
$$\ldots$$
$$\mathrm{v}_\mathrm{i}'' = (6-i)c_2 u \frac{A}{\omega}; \tag{4}$$
$$\ldots$$
$$\mathrm{v}_5'' = c_2 u \frac{A}{\omega}.$$

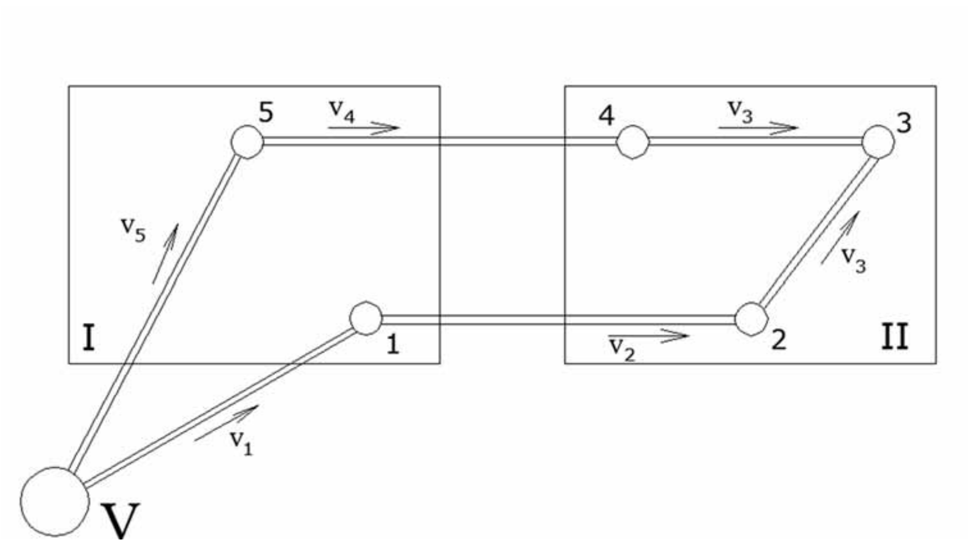
Let the moment the liquid comes in contact with the point of the signaling device, hydraulic grade line be $a - a_1$ and with the point of the signaling device in the i -th head be $b - b_1$ (fig.5).

From fig.5, we have

$$H_{i-1}' = \Delta h_{i-1} + \sum h_{i-1}';$$
$$H_{i-1}'' = \Delta h_{i-1} + \sum h_{i-1}''; \tag{5}$$

where Δh_{i-1} is the difference between points of signaling devices in the i-th and the first measuring heads; $\sum h_{i-1}'$ $\sum h_{i-1}''$ are total energy losses in sections between the first and i -th measuring heads.

Taking into account that $\sum h_{i-1} = \sum_{j=2}^{i} K_j \mathrm{v}_j$, expressions for total energy losses can be written as



3) Close-loop system

Movsesyan R.A., Barkhudaryan A.M. 1975).

$$\sum h'_{i-1} = c_1 u \frac{A}{\omega} \sum_{j=2}^{i} (6-j) K_j;$$

$$\sum h''_{i-1} = c_2 u \frac{A}{\omega} \sum_{j=2}^{i} (6-j) K_j.$$

Introducing $c_1/c_2 = m$, we get

$$\sum h'_{i-1} = m \sum h''_{i-1}$$

then instead of (5), we have

$$\Delta h_{i-1} = H'_{i-1} - m \sum h''_{i-1};$$
$$\Delta h_{i-1} = H''_{i-1} - \sum h''_{i-1}; \quad (6)$$

from which a formula for determining distances between levels has been derived

$$\Delta h_{i-1} = \frac{mH''_{i-1} - H'_{i-1}}{m-1} \quad (7)$$

or

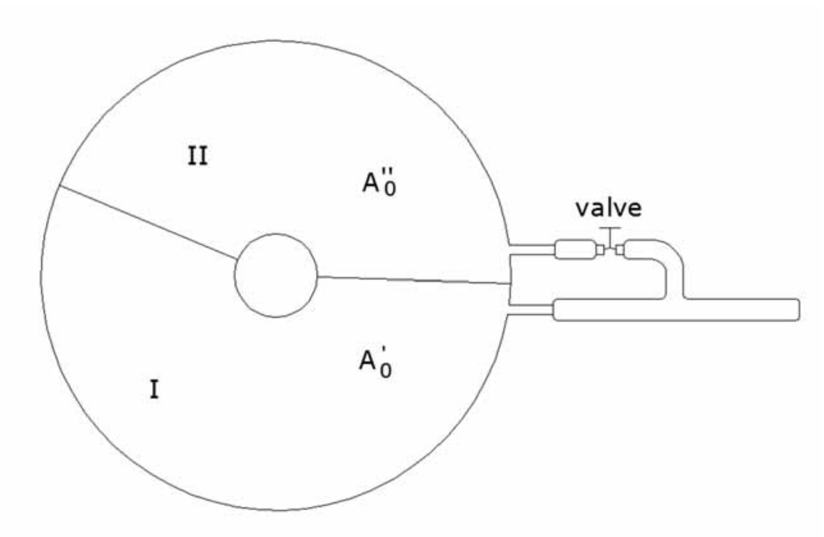
$$\Delta h_{i-1} = \frac{c_1 u}{N_0 (m-1)} \left(N''_i - N'_i - N''_1 + N'_1 \right)$$

where N_0 is the number of impulses, coming into the control unit per unit time:

$$c_1 = \frac{A'_0 + A''_0}{A'_0 + A''_0 + 5A} \quad .$$

4. CLOSE-LOOP SYSTEM OF HYDRODYNAMIC LEVELING

Suppose that the hydrodynamic leveling system a is close-loop one (fig.3). It is evident that at equal lengths of



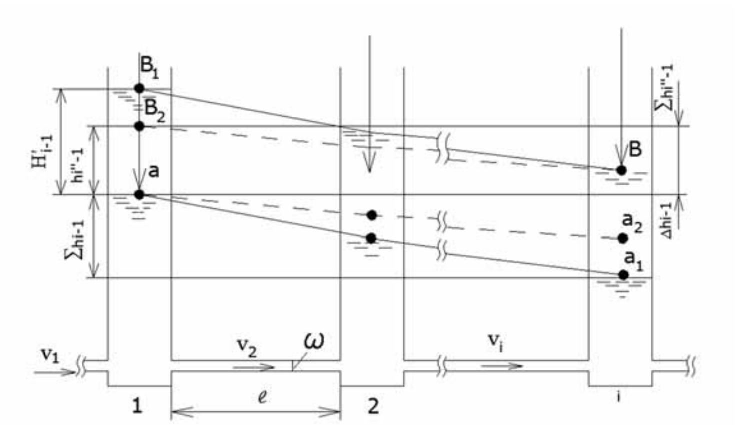
4) Two-sectional back

connection hoses and diameters of measuring heads (vessels) the third transducer will be boundary, that is the liquid enters there in from both sides.
Then velocities of the liquid motion over separate sections are defined as

$$\begin{aligned} v_1 = v_5 = 2{,}5cu\frac{A}{\omega}; \\ v_2 = v_4 = 1{,}5cu\frac{A}{\omega}; \\ v_3 = 0{,}5cu\frac{A}{\omega}. \end{aligned} \quad (8)$$

The close-loop system by the boundary transducer is conventionally divided into two open-loop ones, in that the boundary (third) transducer receives a part of discharge from one side and the rest – from the other.
The difference of the mark of the signaling device's point of the third transducer relative to the first one is determined by the formula (7).

It is not difficult to see that at $i > 3$, the difference of the mark of the third signaling device relative to i-th is determined by the following formula



5) Piezometric lines

$$\Delta h_{3-i} = \frac{c_1 u}{N_0(m-1)}\left(N_3'' - N_3' - N_i'' + N_i'\right); \qquad (9)$$

Then, when $i > 3$ we have

$$\Delta h_{i-1} = \Delta h_{3-1} - \Delta h_{3-i} = \frac{c_1 u}{N_0(m-1)}\left(N_i'' - N_i' - N_1'' + N_1'\right)$$

Thus, it has been find out that in both open-loop and close-loop hydrodynamic leveling systems the distances between levels of points are determined by the same (7) formula.

5. CONCLUSIONS

- in determining distances between levels of points there is no need to carry out measurements the level of the liquid in the regulating tank;
- in the section under consideration the value of energy loss does not take part in the formula of distances between levels of points;
- temperature impact on measurement accuracy is excepted, because measurements are made one after another, practically, temperature during that time can be regarded as constant;
- application of the hydrodynamic leveling method assures high accuracy of measurement in erecting work.

BIBLIOGRAPHY

Vasiutinski. I.Yu.,(1976). *Hydrostatic Levelling.* Moscow: Nedra. (in Russian)

Movsesyan R.A., Barkhudaryan A.M. (1975). *Errors of hydrodynamic nature in systems for hydrostatic leveling with a number of communicating vessels.* Izvestiya vuzov, Geodeziya i aerofotosjomka, 6, 21-29 (in Russian).

Movsesyan R.A., Barkhudaryan A.M. (1976). *Theoretical basis of hydraulic leveling method*. Izvestiya vuzov, Geodeziya i aero-fotosjomka, 1, 9-14 (in Russian).

THE USE OF FUZZY INFERENCE SYSTEMS TO PROVIDE MORE INTELLIGENT HOSPITAL MANAGEMENT SYSTEM

Amin Basiri [1], Anahid Basiri [2], Pouria Amirian [3]
[1] Azad University of Qazvin, Iran
[2] The University of Nottingham, UK
[3] The University of Oxford, UK
email: [1]amin_bassiri@yahoo.com, [2]anahid.basiri@nuim.ie, [3]amirian@cs.nuim.ie

Keywords

building management system (BMS), fuzzy inference system, hospital heating and ventilation system

ABSTRACT

Nowadays minimizing energy consumption becomes one of the most important concerns of human. One of the best solutions for this, is the Building Management System (BMS) which can reduce energy consumption of the buildings up to a significant degree A BMS is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. Since hospitals' electrical and mechanical systems have a direct effect on quality of health services provided by clinicians. In this regard, this paper shows the implementation of fuzzy inference engines to make the building management system more intelligent. Heating and ventilation systems of Laleh hospital, in capital city of Iran are now under control of such system.

1. INTRODUCTION

Building Management Systems are mostly applied in buildings which are equipped with different types of mechanical, electrical, and plumbing systems. Systems linked to a BMS typically consume 40% of a building's energy usage; if lighting is included, this number approaches 70%. BMS systems are quite important component for energy management. Now over ten thousand square meters, half of the buildings in the United States use building management systems and more than ten percent of the energy are being saved. Controlling, monitoring, optimizing and reporting are four basic applications of BMSs. One of the widely used examples of these applications is the control of heating and ventilation and air-conditioning. For example, in order to run the ventilation system in summer, automatic shutters can be closed when it gets warmer than specific degree or the blinds and curtains are open when it rains.

In order to higher the intelligence and also performance of a BMS, it is possible to use a fuzzy inference engine. Since Fuzzy Inference (FI) can take non-numeric input variable, which is called linguistic variable, such as "cold", "warm", "high", "near", etc. as well as numeric variables as its inputs. Such phrases, i.e. linguistic variables, are frequently used by experts and this capability of FI let us to translate experts' knowledge into rules and conditions without any extra effort and mathematical interpretation. For example, one of the rules that control the output temperature of the hot deck heating is used is:

If the air is warm, the controller valve should be closing slowly"

"Warm" and "slowly" are not a mathematically precise concepts. Such words, for control heating and ventilation of buildings are used by experts as human will understand them. However, with help of fuzzy inference system it is possible to make the machines, software and hardware understood what "warm" and "slowly" means.

The control and maintenance of heating and ventilation systems of Laleh Hospital in Tehran, Iran, has been equipped with such inference system to make the BMS less manual and more intelligent. BMSs have a significant impact on the healthcare services since they can provide hospitals and their mechanical and electrical systems with higher performance and reliability. In this regard, we have focused on implementation of fuzzy inference system in Hospital Management System to have more intelligent management systems and automatically delivery of better and efficient healthcare services. This paper is structured as follows; the second section outlines the principles and fundamental concepts in building management systems. Section three is focused on the principles of fuzzy inference engine are in brief. In the fourth section the implementation and practical results are explained and finally conclusion and future work are given.

2. BUILDING MANAGEMENT SYSTEM (BMS)

Building Management System (BMS) is one of the most practical approaches to optimize buildings energy consumption. It controls different parts of the building using predefined conditions and rules. A BMS help mechanical and electrical components to provide better services, minimize their energy consumption, and make them more efficient and productive.

The main advantages of using building management systems is to create a favorable environment in the building, significantly reduce of costs related to maintenance, optimization and energy saving, monitoring and control of all areas using only one PC or even mobile device.

System control is one of the most important applications of BMS. This paper focuses on the implementation of fuzzy inference systems in heating, ventilation and air conditioning system of a specialized hospital in Tehran, Iran, so this section dedicates to this.

One of the most important applications of electrical systems, which can be controlled by building management systems, is heating, ventilation and air conditioning (HVAC). Using a HVAC can help to optimize the energy consumption (Energy Saving), reduce maintenance costs; create comfort for users, increase security and flexible. Each benefits from building management systems Control heating and ventilation will be described in more detail. Smart heating and ventilation can have different applications. For example, at presence or absence of people in a patient room, system changes its action status (from on to off). A thermostat controls the temperature of the indoor temperature to keep it constant. Efficient pumps, chiller, cooling tower, torch and all mechanical devices can be controlled by such system. The system can also be controlled remotely in a more comfortable manner. It can be controlled by a network-based software (Web-based). In this case one can predefine some scenarios for the computer to do some repetitive tasks. For example, with a temperature control system in different parts of the house, it can get the status of all electrical equipment every 15 minutes and use the remote control if needed.

What this paper tries to show is the use of fuzzy inference engine for intelligent hospital management system to control the heating and ventilation system. So, the next part the basics of fuzzy inference systems are discussed.

3. FUZZY INFERENCE SYSTEM

A fuzzy inference system (FIS) is a system that uses fuzzy set theory to map inputs (features in the case of fuzzy classification) to outputs (classes in the case of fuzzy classification). A fuzzy inference engine uses fuzzy logic principles for the composition rules, which are usually in the form of if - then statements stored in the database (Sugeno, 1985). To compute the output of a FIS one must go through six steps:

- determining a set of fuzzy rules
- fuzzifying the inputs using the input membership functions,
- combining the fuzzified inputs according to the fuzzy rules to establish a rule strength,
- finding the consequence of the rule by combining the rule strength and the output membership function,
- combining the consequences to get an output distribution, and
- defuzzifying the output distribution (this step is only if a crisp output (class) is needed).

Fuzzy rules are a collection of linguistic statements that describe how the FIS should make a decision regarding classifying an input or controlling an output. Fuzzy rules are always written in the following form:

If (input1 is membership function1) and/or (input2 is membership function2) and/or , then (output is output membership function).

For example, one could make up a rule that says:

If temperature is high and humidity is high then room is hot.

There would have to be membership functions that define what we mean by high temperature (input1), high humidity (input2) and a hot room (output1). The purpose of fuzzification is to map the inputs from a set of sensors, such as thermometers, to values from 0 to 1 using a set of input membership functions. These input membership functions, can represent fuzzy concepts such as “high” or “low”, “hot” or “cold”, etc. When choosing the input membership functions, the definition of what we mean by “high” and “low” may be different for each input.

In the next section, these six steps are explained with applications to hospital ventilation and air conditioning management systems.

4. IMPLEMENTATION

In order to make an intelligent building management system, inference and intelligent decision-making ability must be added to the system. This paper seeks to obtain the inference engine for intelligent control of building heating and ventilation system. As described in the previous section, for implementation of fuzzy inference engine, first fuzzy input variables must be defined. Then the inference rules need to be added to the knowledge. As is shown in Figure 1, a fuzzy inference engine is used to control heating and ventilation system of a specialized hospital in Tehran, Iran. The input of the heating coil has four parameters; temperature of cooling coil, temperature of heating coil and the outside air temperature and humidity (respectively with following names:DamayeKhoroojiAzKoyle-Garmayesh, DamayeKhoroojiAzKoyleSard, DamayehavayeBiroon, RotoobateFaza)

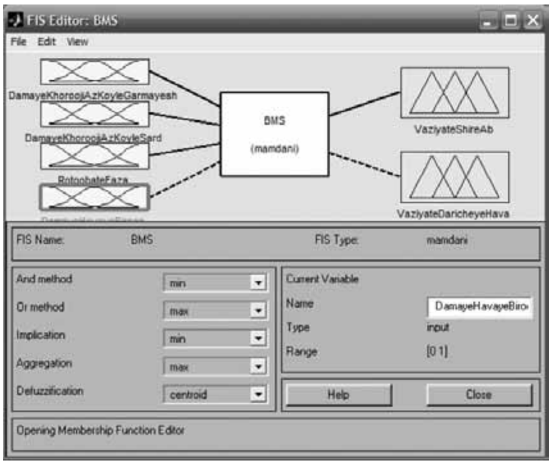


Fig. 1. Components of the fuzzy inference engine to control the heating and ventilation system of the Laleh Hospital

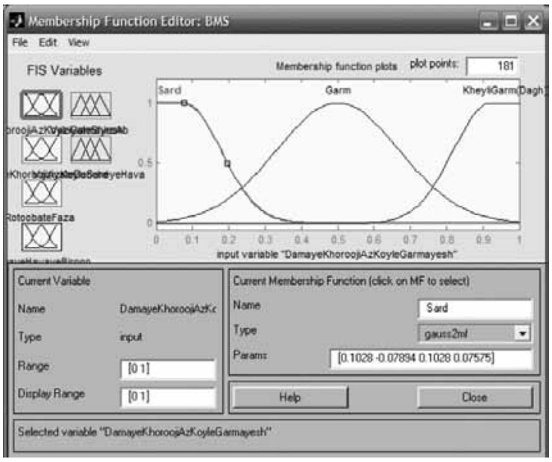


Fig. 2. Temperature output variable membership function of the heating coil

There are two outputs for the status of the vent and the status of the valve (VaziyateDaricheyehava, VaziyateShireAb). Next step is to assign the inputs variables' membership functions. Figure 2 shows the membership function of the first input. As shown in this figure2, the values of these variables are categorized into three classes, cold, warm and hot. These three classes with names Sard, Garm and KheyliGarm (Dagh) are marked. The input membership functions similar to a Gauss curve have been selected and this selection has been made based on experts' comments and experiences.

After introducing all inputs' membership functions, the inference rules should be defined. The purpose of these rules is making the system able to infer. For example, assume that the four parameters are in their normal condition and temperature has been set 22 ° C, which is recommended in most cases. In this case, the weather is almost perfect for the user; the air valve should remain unchanged. In Figure 3, all rules in the knowledge base are shown. The first row corresponds to a state in which it was described in this example.

This rule has to be defined as:

If (DamayeKhoroojiAzKoyleGarmayesh is Garm) and (DamayeKhoroojiAzKoyleSard is Sard) and (Rotoobate-Faza is Monaseb) and (DamayehavayeBiroon is Monaseb) then (VaziyateShireAb is Monaseb) and (Vaziyatedari-cheyeHava is BedooneTaghirEdameDahad)

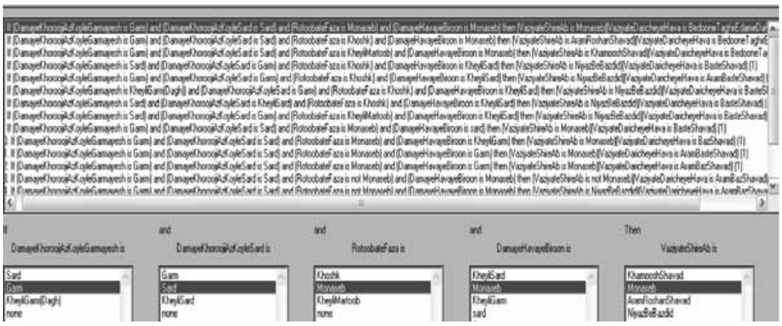


Fig. 3. Rules of knowledge base

Now the building management system can use multiple sensors to measure temperature, humidity, etc. Then according to the rules defined and stored in the knowledge base, the statuses of the two output parameters are determined and the corresponding action is performed. For example, the vent becomes open. Such system has been implemented to the control mechanism of the heating and ventilation system located in Laleh specialized hospital, Tehran, Iran. The results of the work of reducing the 5% and 25% energy and maintenance cost respectively (for one year test interval). In addition less time spent on manual work and less need for human expert are other advantages of using smart management system based on fuzzy inference system.

5. CONCLUSIONS

Building Management System (BMS) is one of the most practical approaches to optimize buildings energy consumption. It controls different parts of the building using predefined conditions and rules. System control is one of the most important applications of BMS. This paper focuses on the implementation of fuzzy inference systems in heating, ventilation and air conditioning system of a specialized hospital in Tehran, Iran. The results of the work of reducing the 5% and 25% energy and maintenance cost respectively (for one year test interval). In addition less time spent on manual work and less need for human expert are other advantages of using smart management system based on fuzzy inference system.

BIBLIOGRAPHY

[1] Dubois D., Prade H., Janvier 2005. *Fuzzy intervals versus fuzzy numbers: is there a missing concept in fuzzy set theory?* Proc. of the 25th Linz seminar on Fuzzy Set Theory, Linz, Austria.

[2] Sugeno, M., *Industrial Applications of Fuzzy Control*. 1985. North-Holland, New York.

[3] Zadeh L.A., 1979. *Fuzzy sets as a basis for a theory of possibility*. Fuzzy Sets and Systems, 1: 3-28.

NUMERICAL STUDIES FOR RETOFFITTING OF CONCRETE COUPLING BEAMS WITH STIFFENED LATERALLY RESTRAINED STEEL PLATE

POSTER

Bei Cheng[1], C.Shi, ChengZhi Qi

[1]Beijing University of Civil Engineering and Architecture, China

Beijing Research Center for Engineering Structures and New Materials, China

email: [1] chengbei@bucea.edu.cn

Keywords

deep coupling beams, seismic retrofitting, adhesive,bolt connection

ABSTRACT

Existing deep reinforced concrete (RC) coupling beams with low shear span ratios and conventionally reinforced shear stirrups tend to fail in a brittle manner with limited ductility and deformability under reversed cyclic loading. Previous studies have developed a new retrofitting method with stiffened laterally restrained steel plate (SLRSP) for existing deep RC coupling beams. Experimental studies have revealed that the types of bolt connection and bolt slipping have great influence on the performance of retrofitted coupling beams. Dynamic set bolt connection with adhesive injection can help the specimens achieve much better shear capacity and deformability. In this study, numerical studies were conducted to investigate the effects of the properties of the adhesive, with or without the adhesive on the behavior of retrofitted coupling beams.

1. INTRODUCTION

Many old reinforced concrete (RC) buildings in developed countries need to be strengthened due to the aging of construction materials, changes in functional use or new design loading requirements. Coupled beams in coupled shear walls are very important structural components that provide the necessary lateral strength, stiffness and deformability for the whole building to resist extreme environmental loads, including wind and earthquake. To ensure the desired behaviour of coupled shear wall systems, coupling beams should be sufficiently strong for resisting wind load, and have good energy dissipation ability and low strength degradation rate for seismic resistant applications. While existing deep coupling beams inevitably failed from diagonal tension when the shear reinforcement was insufficient (Paulay, 1971). In past decades, the design of many concrete buildings (including coupling beams) in China and Hong Kong did not take into account earthquake actions. According to the new design codes, many existing coupling beams are found to be deficient in shear. Sudden failure of these coupling beams will threaten the safety of the building.

Compared with the research about strengthening of RC floor beams, only a few studies are applicable to strengthening existing RC coupling beams. Harries et al. (1996) studied a shear strengthening method for existing coupling beams with a span-to-depth ratio of 3.0. In their study, the retrofitting measures involved a number of different attachment methods to fix the steel plate to one side of the coupling beams. They found that the composite method of bolting with epoxy bonding to attach the steel plates both in the span and at the ends performed the best. Minor plate buckling was found in his tests. Most of the previous studies focused on coupling beams with span-to-depth ratios larger than 2.0. Since the widths of the door and window openings usually range from 1.0 to 1.5m, most coupling beams are quite short and deep. Cheng and Su (2011a&b) experimentally studied the use of a laterally restrained steel plate (LRSP) without stiffeners to retrofit deep concrete coupling beams with a span-to-depth ratio of 1.1. In their test, thin mild steel plates were utilized. The steel plate started to develop a diagonal tension field after the onset of global buckling at the early stages of loading and exhibited nonlinear behavior at relatively small inter-story drift ratios. Due to the post-buckling loading capacity and tension field action in the steel plate, LRSP retrofitted coupling beams failed in a ductile manner. However, shear buckling of steel plate in the early stages usually results in reduced strength, stiffness and energy dissipation capacity accompanied by significant pinching. Adding steel stiffeners to the steel plate is a good way to defer the shear buckling and large-scale experiments of LRSPs with stiffeners have been carried out (Cheng and Su, 2015reviewing).

In this study, a nonlinear finite element model using the finite element program ABAQUS was developed to investigate the whole behaviour of the retrofitted deep coupling beams with stiffened laterally restrained steel plate (SLRSP) such as the load-rotation curves and failure characteristics. The effects of the properties of the adhesive and with or without the adhesive in the gap between the concrete and bolt on the behavior of retrofitted coupling beams were discussed.

2. EXPERIMENTAL STUDIES

Three specimens with the same dimensions and reinforcement specifications (see Fig.1), but different retrofitting schemes, were fabricated and tested. The details of reinforcement details of the specimens and test setup, loading procedure can be found in Cheng&Su (2011a). The first specimen DCB8 with a plain RC arrangement was used for control purposes. The LRSP method and stiffeners were all applied to Specimens DCB9 to DCB10. Stiffeners are structural elements connected to the steel sheet by continuous fillet welds. Rigid stiffeners are used to ensure that the plate can reach its full plastic strength and avoid overall buckling. Two types of bolt connection are adopted in the specimens. One is the general bolt connection(adopted in DCB9) which screws the bolts by tightening torque to about 0.3 kNm (according to China Standard Q/STB 12.521.5-2000). The other is the dynamic set bolt connection(adopted in DCB10) which minimizes any possible slippage between various components at the connections by injecting adhesive to fill the gaps between the bolt shank and surrounding concrete (see Fig.1). The experimental study revealed that the use of laterally restrained steel plate with stiffeners for the seismic retrofitting of concrete deep coupling beams has demonstrated effectiveness in increasing deformability and energy dissipation while reducing strength and stiffness degradation. Also, the retrofitted beams failed in a ductile manner. The type of bolt connections used is found to have significant effects on the performances of the retrofitted coupling beams. Dynamic set bolt connections with adhesive to fill in the gap between the concrete and bolt can alleviate bolt slippage and make the retrofitted coupling beams achieve a desirable seismic response.

3. NUMERAL STUDIES

The finite element software ABAQUS 6.14-2 (DSSC, 2014) was utilized to investigate the whole behaviour of the retrofitted deep coupling beams with stiffened laterally restrained steel plate (SLRSP). All the nodes along the edge of the vertical wall on the right were fixed, while the nodes along the vertical edge on the left were constrained to undergo equal horizontal displacements. This would maintain parallelism of the two wall panels in the loading process and thus simulate the conditions of equal beam-end rotations in real structures.

In the finite element model, six parts were created including concrete, reinforcements cage, stiffening rib, steel plate, bolts and the loading rigid bodies. The reinforcement cage consists of the longitudinal bars and stirrups. The concrete, stiffeners, steel plate, bolts and the rigid bodies were modeled using solid C3D8R elements. The reinforcement cage was modeled using T3D2 truss elements. The elements size was about 30mm for the whole model. The reinforcement cage was embedded into the concrete part. The stiffeners were tied to the steel plate. For DCB9 without adhesive in the gap between the concrete and bolt, a general contact element was selected. In its normal direction, the contract “hard” is made and in its tangential direction, the friction factor of 0.15 is selected to simulate the bolts slipping. For DCB10 with adhesive filled in the gap between the concrete and bolt, an adhesive contact element was selected. The geometry of the model and the finite element mesh are shown in Fig.2. The deformation mode and stress distribution of DCB10 are shown in Fig.3.

4. VERIFICATIONS OF NUMERICAL MODELS USING EXPERIMENTAL RESULTS

To verify the proposed model, the numerical results such as the load-rotation curves, crack pattern, bolt slipping and shear stress in the steel plate were compared with the experimental results.

• *4.1 Load-rotation curves*

Fig.4 shows the agreement of load-rotation curves obtained from the NLFEA and the experimental studies. For DCB9 without adhesive filled in the gap between the concrete and bolt, due to the significant bolt slips, the steel plate did not deform in the early rotation level (< 0.04 rad). The post-peak behavior of DCB9 is very brittle. Compared with DCB9 and DCB10, it can be found that the post peak behavior of DCB10 with adhesive filled in the gap between the concrete and bolt connection became ductile. These results show that the NLFEM model can predict the behaviors of retrofitted coupling beams accurately.

• *4.2 Crack Patterns and Failure Behaviors*

Fig.5 compared the distribution of SDEG (scalar stiffness degradation) of the two specimens. When the concrete cracking occurred, the stiffness of the cracking region will be degenerated. The value of 0 means no damage. The value of 1 means completely damage. The value between 0 and 1 means the occurring of cracking. Through the distribution of SDEG value, cracking pattern in the specimens can be predicted. From comparison of DCB9 with DCB10 at the same rotation of 0.01, it can be obviously found that the SDEG value of DCB9 is larger than that in DCB10.This means at the same rotation, more cracking happened in DCB9 which resulted in rapid stiffness degradation. This can also explain why DCB9 behaved in a brittle manner.

• *V4.3 Longitudinal Rotation of Bolts Connections*

Fig.6 shows the comparison of the longitudinal rotation of bolt connections from the experimental and numerical results. It can be seen that numerical results matched well with the experimental results. For DCB10 with dynamic set bolt connection, the longitudinal rotation is much less than that of DCB9 with general bolt connections. This can confirm that dynamic set bolt connection can provide enough stiffness.
4.4 Shear Stress Distributions in Steel Plates
Fig.7 shows the comparison of the experimental and numerical results of the shear stress in steel plate of DCB9 and DCB10. Fig.7(b) and 7(d) give the numerical results of shear stress in steel plate at the same rotation 0.02 rad. The values of shear stress got from the numerical study are generally higher than that of experimental results. It can be found that the value of shear stress of DCB10 is much higher than that in DCB9. This is due to the reason that for DCB10 with adhesive injected in the bolt connections, steel plate and concrete beam can work together to resist part of the shear force. While for DCB9 with general bolt connections, steel plate didn't deform due to the large slipping of bolt connection at the early loading stage. Therefore the steel plate didn't help to resist much shear force at the early loading stage.

• *4.5 Effect of Adhesive in Bolt Connections*

Turon(2007) advised that the stiffness of the cohesive elements should be 1-50 times to the connected material's stiffness. To study the effects of stiffness of adhesive on the performances of retrofitted beams, 2Gpa, 200Gpa and 20000Gpa were selected for the stiffness of adhesive. It can be seen from Fig.8 that the loading capacity of the retrofitted beam increased with the incensement of stiffness of adhesive. However, the load-rotation curves are quite similar for the stiffness of 200Gpa and 20000Gpa. This means when the stiffness of adhesive was strong enough to ensure the plate attain the load capacity, with the incensement adhesive stiffness, the retrofitted beams may achieve the same strength in the large rotation range.

5. CONCLUSIONS

This paper presents the numerical study of deep coupling beams retrofitted with stiffened laterally restrained steel plate (SLRSP). The main findings are summarized as follows:
This study confirmed that the present NLFEA accurately predicted the load-rotation curves, failure patterns and stress distributions of the SLRSP retrofitted coupling beams. The new model is simple, computationally efficient and able to capture the overall behavior.
The type of bolt connections used is found to have significant effects on the performances of the retrofitted coupling beams. Dynamic set bolt connections with adhesive to fill in the gap between the concrete and bolt can alleviate cracking in concrete, bolt slippage and make the retrofitted coupling beams achieve a desirable seismic response. If the stiffness of adhesive is strong enough to ensure the plate attain the load capacity, with the incensement adhesive stiffness, the retrofitted beams may achieve the same strength in the large rotation range.

ACKNOWLEDGEMENTS

The work described in this paper has been fully supported by the National Natural Science Foundation (Project No.51208023).

BIBLIOGRAPHY

Paulay, T., *Coupling beams of reinforced concrete shear walls*, Journal of the Structural Division, 1971, Vol. 97 (ST3), pp.843-862.

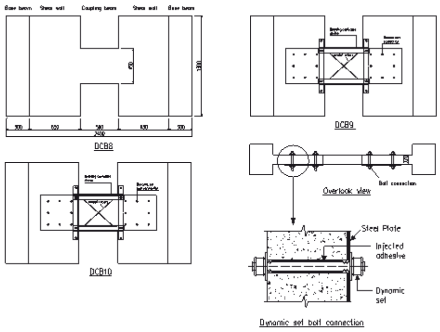
Harries, K.A., Cook, W.D., Mitchell, D., *Seismic retrofit of reinforced concrete coupling beams using steel plates*, ACI SP-160, 1996, Vol. 6(1), pp.93-114.

Su, R.K.L., Cheng, B., *Plate strengthened deep reinforced concrete coupling beams*, ICE-Structures and Buildings, 2011a, Vol. 164(1), pp.27-42.

Cheng, B., Su, R.K.L., *Retrofit of deep concrete coupling beams by laterally restrained side plates*, Journal of Structural Engineering, 2011b, Vol. 137(4), pp.503-512.

Cheng, B., Su, R.K.L., *Laterally restrained steel plate with stiffeners for seismic retrofitting of concrete coupling beams,*2015, submitted to The International Journal of Advanced Steel Construction, under reviewing.

Turon A., Dávila C. G., Camanho P.P., Costa J. *An engineering solution for mesh size effects in the simulation ofdelamination using cohesive zone models*[J]. Engineering Fracture Mechanics, 2007, 74(10), pp.1665-1682.



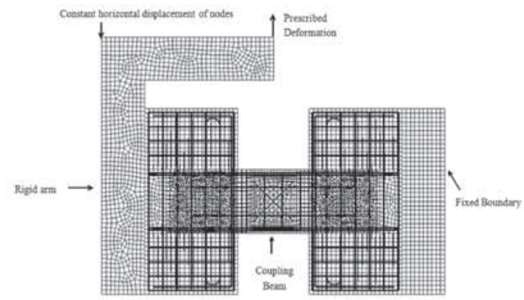


Fig. 1. Details of test specimens

Fig. 2. Finite element model

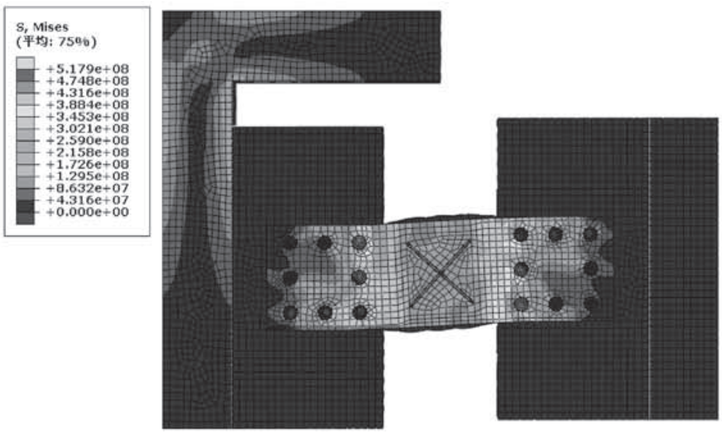
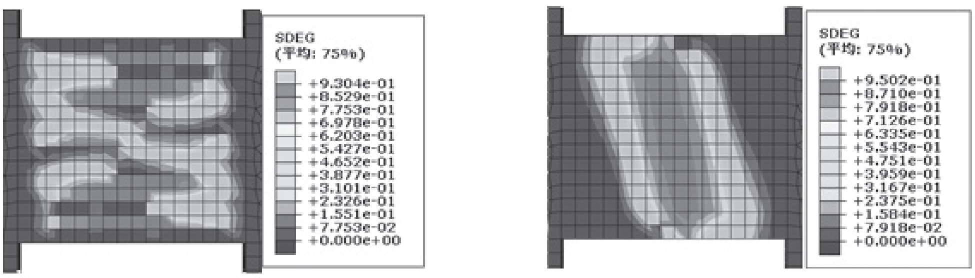


Fig. 3. Deformation and stress distribution of DCB10



(a) (b)

Fig. 4 SDEG value at the rotation of 0.01rad: (a) DCB9, (b) DCB10

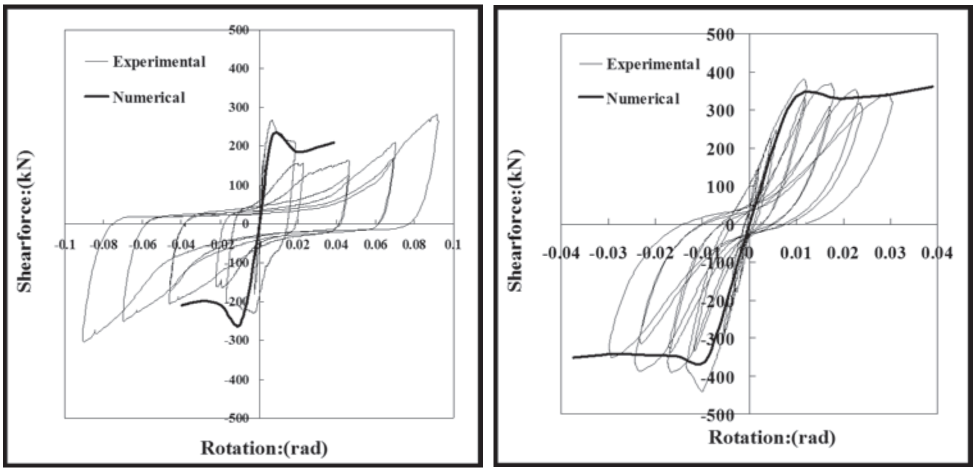


Fig. 5. Experimental and numerical load-rotation curves: (a) DCB9 (b) DCB10

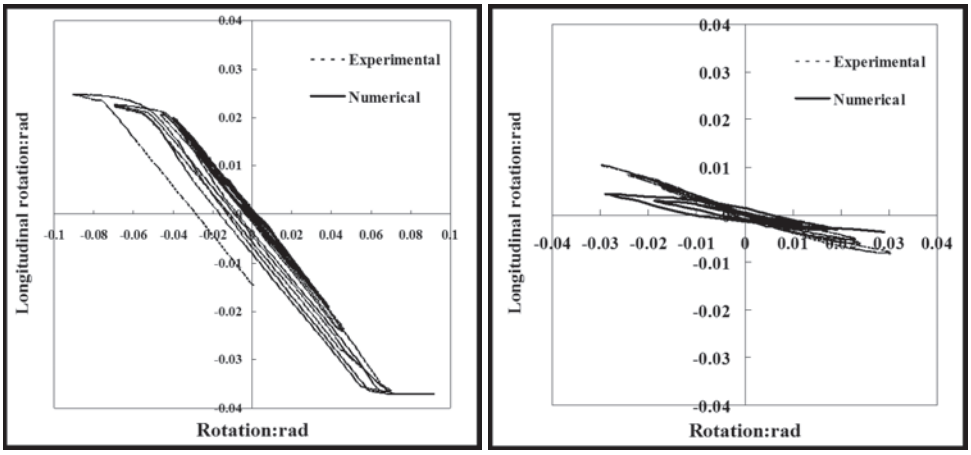


Fig. 6. Longitudinal rotation of bolt connection: (a) DCB9 (b) DCB10

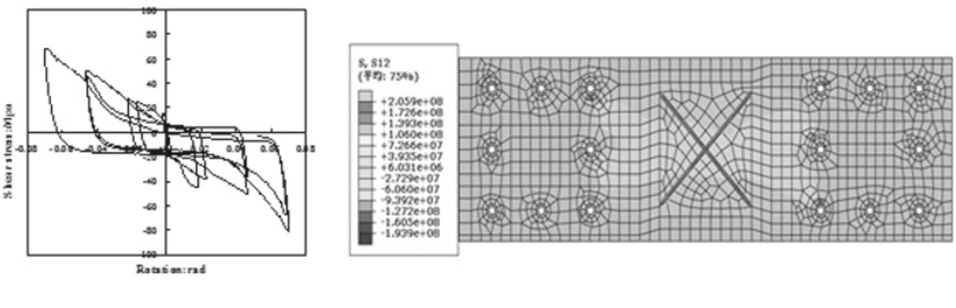
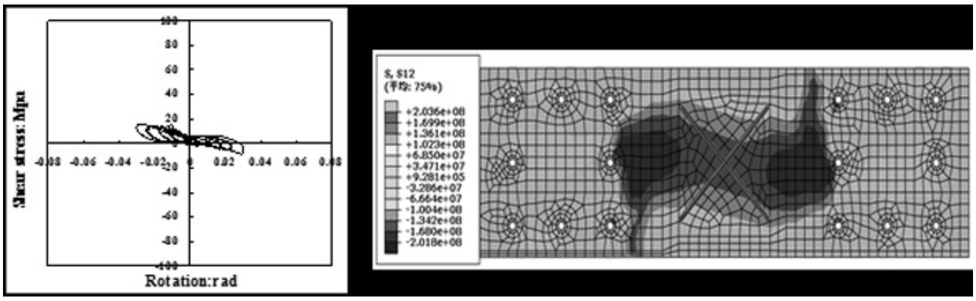


Fig. 7. Shear Stress in the experiment and numerical(at the rotation of 0.02):(a),(b)DCB9 (c),(d)DCB10



(c) (d)

Fig. 8. Shear Stress in the experiment and numerical(at the rotation of 0.02):(a),(b)DCB9 (c),(d)DCB10

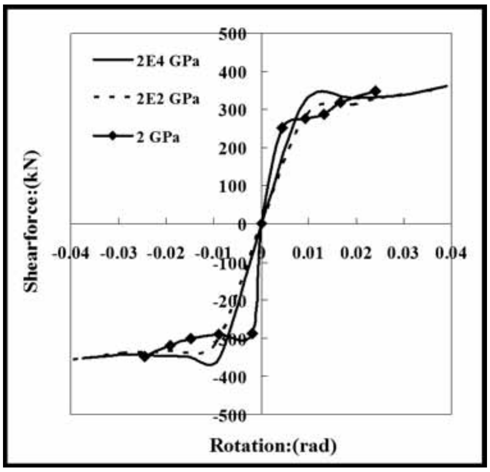


Fig. 9. Skeleton curves in three different kinds of stiffness for DCB10

CALCULATION OF THIN-WALLED PREFABRICATED TYPE SHELLS WITH MODEL OF PLASTIC-RIGID BODY

Zviad Churchelauri[1], Gela Kipiani[2]

[1]Georgian Technical University

[2]Georgian Aviation University

email: [1]zviadoo@gmail.com, [2] gelakip@gmail.com

Keywords

prefabricated element, plasticity, variation equation

ABSTRACT

In the work are studied the change of load bearing capacity of prefabricated elastic-plastic prefabricated shell type structures accordingly of number of prefabricated elements. The issue of shell type prefabricated structure optimal design at discontinuous solution of prefabricated element and by variation equation of elastic-plastic equilibrium is developed. The dependencies between deformations and loads are obtained.

1. INTRODUCTION

The up-to-date construction is studies the lot of objects, the analysis of that due their complexity, is related with application of analytical and numerical methods, hence it makes certain requirements to designers for implementation of new methods of analysis and design. The theory of thin-walled spatial structures with respect of rheological properties of materials is divided into several parts. In the recent years great attention is paid for to problems of physical non-linearity, plasticity, creeping, durability and strength.

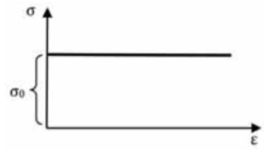
In the case of complex loading in comparison with theory of deformations more perfect result give's the theory of elasticity. Especially will be calculated the construction of yield surface. This and similar specific issues that are related to plasticity properties of shell's materials are considered in lot of works, in particular A.O. Savchuko [1], S.G. Lekhnitski [2], N.M. Beliaes and A.K. Sinitski [3], G.S. Shapiro [4], R.M. Tskhvedadze [5]. In the book of V. Olshak and A. Savchuk [6] are investigated the situations, in that material of shell is linearly viscous-elastic and is in steady creeping, or in elastic-plastic state. In the same book are considered the works of A.A. Ikiushinski [7], I.N. Rakhotnikov [8] and others are considered reinforced concrete shells, in that are studies the limiting state and load-bearing possibilities of shells.

From the review of mentioned literature is clear that in the case of elastic-plastic state of thin-walled structures the problem of analysis is topical and is being in the stage of actively developing.

2. BACKGROUND

In point of engineering view the limiting state of structure is characterized by its so significant change in initial dimensions and shapes that structure the further operation of it makes impossible. It is clear that prior the reaching of limiting state in structure occurs separate scattering plastic areas, the impact of that is still insignificant and the structure would been considered as rigid. But with increase in loading begin the expansion of plastic areas and finally when the external forces reaches the certain "limiting state" that is called as load-bearing capacity of structure , the structure "creeps as whole" that is characterized by infinite increasing of deformation rate.

In the conditions of failure plastic deformation significantly exceeds the elastic ones due that latter would be beglected. From such description we obtain ideal plastic-rigid model of real deformable body (Fig. 1). Exactly this model will be applied at determination of load-bearing capacity.



1). Plastic-rigid model

The origination of single-axis stresses state of plastic deformation is stipulated by reaching of limiting values of according material creeping σ. In the plates and depressed shells, in that the stresses state of elementary layers is planar, the origination of plastic areas is carried out by σxx, σyy normal and σxy shear stresses.
The condition that would be satisfied the stresses in certain point of deformable rigid body to occur in it plastic deformation is known as plasticity or creeping condition. Exist few conditions for the case of complex stressed state. One of them is known as Hoover-Mises conditions that in conditions of planar stressed state will be as [9]

$$f(\sigma_{ij}) = f(\sigma_{xx}, \sigma_{yy}, \sigma_{xy}) = \frac{\sigma_{yy}^2}{\sigma_{xx}^2} - \frac{\sigma_{xx}\sigma_{yy}}{\sigma_{xx}\sigma_{xy}} + \frac{\sigma_{yy}^2}{\sigma_{xy}^2} + \frac{\sigma_{xy}^2}{\tau_x^2} - 1 = 0, \quad (1)$$

where τ – is the yield point of material at shear, σ_{yx}, σ_{xy} – are the yield points at tension accordingly in x and y directions.
When $f(\sigma_{\_ij})<0$ the material is assumed as non-deformable and when $f(\sigma_{\_ij})=0$ the material has creeping properties. Grounded only on yield condition is impossible the fully characterizing of mechanical state of plastic-rigid body. Is necessary also to know yield accompanying law. The later commonly implies the existence of equate to yield function $f(\sigma_{\_xx},\sigma_{\_yy},\sigma_{\_xy})$ of plasticity potential.
Therefore is implied the existence of following equalities

$$\dot{\varepsilon}_x = \lambda \frac{\partial f}{\partial \sigma_{xx}}; \quad \dot{\varepsilon}_y = \lambda \frac{\partial f}{\partial \sigma_{yy}}; \quad \dot{\omega} = \lambda \frac{\partial f}{\partial \sigma_{xy}}, \quad (2)$$

where ε˙_x , ε˙_y and ω˙ are designating the corresponding rates of deformation, λ – is the called as plasticity coefficient is defined by the formula:

$$\lambda = \left[\frac{1}{3}\left(\sigma_{xx}^2 \cdot \dot{\varepsilon}_x^2 + \sigma_x \cdot \sigma_{yy} \cdot \dot{\varepsilon}_x \cdot \dot{\varepsilon}_y + \sigma_{xy}^2 \cdot \dot{\varepsilon}_y^2\right) + \frac{\tau_x^2 \cdot \dot{\omega}^2}{4} + \right.$$
$$\left. + \frac{h}{36}\left(\sigma_{xx}^2 \cdot \dot{\chi}_x^2 + \sigma_x \cdot \sigma_{yy} \cdot \dot{\chi}_x \cdot \dot{\chi}_y + \sigma_{xy}^2 \cdot \dot{\chi}_y^2\right) + \frac{\tau_x^2}{4}\dot{\chi}^2\right]^{1/2} \quad (3)$$

In the case of depressed double curvature shell the determining the parameters of median surface deformations rate will be defined by formulae:

$$\dot{\varepsilon}_x = \frac{\partial \dot{U}}{\partial x} + \frac{\dot{\omega}}{R_1}, \quad \dot{\varepsilon}_y = \frac{\partial \dot{V}}{\partial y} + \frac{\dot{\omega}}{R_2}, \quad \omega = \frac{\partial \dot{U}}{\partial y} + \frac{\partial \dot{V}}{\partial x}; \quad (4)$$
$$\chi_1 = -\frac{\partial^2 \dot{\omega}}{\partial x^2} + \frac{1}{R_1}\frac{\partial \dot{U}}{\partial x}; \quad \chi_2 = \frac{\partial^2 \dot{\omega}}{\partial y^2} + \frac{1}{R_2}\frac{\partial \dot{V}}{\partial y};$$
$$\chi = \frac{1}{R_1}\frac{\partial \dot{U}}{\partial y} + \frac{1}{R_2}\frac{\partial \dot{V}}{\partial x} - 2\frac{\partial^2 \dot{\omega}}{\partial x \partial y}.$$

The determination of load bearing capacity of engineering structures represents one of the major tasks of structural mechanics. In this direction is developed lot of methods that rather simplifies the solution of this task. One of such method is developed by M. Mikeladze, B. Mikhailov and G. Kipiani that is related to bilateral assessment of structure's load bearing capacity [9, 11]. Accordingly of this method if we designate as Pst the statically allowable value of ultimate loading intensity and as Pk kinematically allowable value of ultimate loading intensity then the true value of ultimate loading P will be equal to maximal value of statically allowable value of ultimate loading intensity and minimal values of kinematically allowable value of ultimate loading intensity. $P_{st} \leq P \leq Pk$. Accordingly of [10] the load bearing capacity of shell from above will be written down as

$$P < P_{pl} + \frac{2h}{\sqrt{3}}\left(\frac{\sigma_{Sx}^2}{R_1^2} + \frac{\sigma_{Sx}\sigma_{Sy}}{R_1 R_2} + \frac{\sigma_{Sy}^2}{R_2^2}\right)^{1/2} \quad (5)$$

where

$$P_{pl} = \frac{\frac{h^2}{\sqrt{3}}\int\left\{\frac{1}{3}\left[\left(\frac{\partial^2 \dot{\omega}}{\partial x^2}\right)^2 \sigma_{xy}^2 + \sigma_{xx} \cdot \sigma_{xy}\frac{\partial^2 \dot{\omega}}{\partial x^2}\frac{\partial^2 \dot{\omega}}{\partial y^2} + \sigma_{xy}^2\left(\frac{\partial^2 \dot{\omega}}{\partial x^2}\right)^2\right] + \tau_x\left(\frac{\partial^2 \dot{\omega}}{\partial x \partial x}\right)^2\right\}^{1/2}}{\int \dot{\omega} dF} \quad (6)$$

is the load bearing capacity of plate the dimensions of that match the covered by shell geometrical dimensions. The load bearing capacity of shell from below will be determined by formula

$$P > \frac{2h}{\sqrt{3}}\left(\frac{\sigma_{Sx}^2}{R_1^2} + \frac{\sigma_{Sx}\sigma_{Sy}}{R_1 R_2} + \frac{\sigma_{Sy}^2}{R_2^2}\right)^{1/2} \quad (7)$$

Let's begin from the case when has not the intermediate hinges, for such shell the load bearing capacity will be determined from above by formula (5). In order to simplify the following calculations let's introduce the dimensionless values ξ and η accordingly of following equalities:

$$x = \xi \ell_2 \quad \text{and} \quad y = \eta \ell_2 = \eta k \ell_1 \quad (\ell_2 = k\ell_1)$$

where $l_{\_1}$ and $l_{\_2}$ represents the lengths of sides in plane. The yield point values $\sigma_{\_xy}$ and τ_x let's express through $\sigma_{\_xx}$ accordingly of following dependencies

$\sigma_{\_xy}=t\sigma_{\_xx}$, $\tau_{\_x}=\sigma_{\_xy}$ $1/\sqrt{3}$.

Accordingly the expression (5) will be as

$$P < P_{pl} + \frac{2h}{\sqrt{3}}\left(\frac{1}{R_1^2} + \frac{1}{R_1 R_2} + \frac{1}{R_2^2}\right)^{1/2} \quad (8)$$

where

$$P_{pl} = \frac{\frac{h^2}{3}\frac{\sigma_{xx}}{\ell_1^2}\int_o^1\int_o^1\left[\left(\frac{\partial^2\dot{\omega}}{\partial\xi^2}\right)^2 + \frac{t}{K^2}\frac{\partial^2\dot{\omega}}{\partial\xi^2}\frac{\partial^2\dot{\omega}}{\partial\eta^2} + \frac{t^2}{K}\left(\frac{\partial^2\dot{\omega}}{\partial\eta^2}\right) + \frac{1}{K^2}\left(\frac{\partial^2\dot{\omega}}{\partial\xi\partial\eta}\right)\right]}{\int_o^1\int_o^1 \dot{\omega}\, d\xi d\eta} \quad (9)$$

With unlimiting of generality for simplify of further calculations let's assume that t=1 and K=1. In such case the given shell transforms into rigidly supported on contour spherical shell, the calculation of that will be reduced to issue of integration of following differential equation

$$\frac{d^4\omega}{d\xi^4} + \omega = \frac{q\ell^4}{Ey} \quad (10)$$

with taking into account of following boundary conditions:

when ξ=0 and ξ=0 $\omega(0) = \omega(1) = 0$

when $\xi = \frac{1}{2}$ $\omega\left(\frac{1}{2}\right) = 0$

In this case due solution of equation (10) in x direction we will have

$$\omega(\xi) = C(2\xi^3 - \xi^2 - \xi^4); \quad (11)$$

The kinematic field of kinematical allowable deflections will be as

$$\omega = \omega(\xi)\cdot\omega(\eta) = C^2(2\xi^3 - \xi^2 - \xi^4)(2\eta^3 - \eta^2 - \eta^4) \quad (12)$$

Let's define the values $\partial^2\omega/\partial\xi^2$, $\partial^2\omega/\partial\eta^2$ and $\partial^2\omega/\partial\xi\partial\eta$. After the certain calculations the obtained equality for plates (9) gives:

$$P_{pl} = \frac{\frac{h^2}{3}\frac{\sigma_{S1}}{\ell_1^2}\int_o^{1/2}\int_o^{1/2}[\theta^2(\xi)\Psi^2(\eta) + \theta(\xi)\Psi(\eta)\Psi(\xi)\xi(\eta) + \Psi^2(\xi)\theta^2(\eta) + \wedge^2(\xi)\wedge^2(\eta)]^{1/2} d\xi d\varphi}{\int_o^{1/2}\int_o^{1/2}\Psi(\xi)\Psi(\varphi)d\xi d\eta} \quad (13)$$

In the denominator of expression (13) integral is calculated accordingly of Simpson cubature formula [12]

$$\int\int f(x,y) = \frac{h\cdot K}{9}(\sigma_0 + 4\sigma_1 + 16\sigma_2)$$

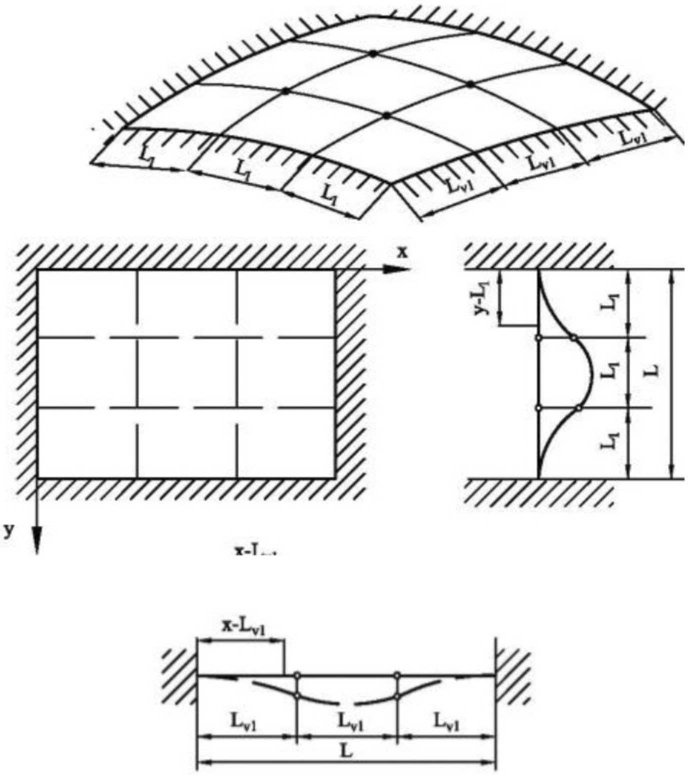


Fig.2 Design scheme of prefabricated shell

where the integration element σ_0 is the summand of in rectangle vertexes; σ_{-1} - is the value of $f(\xi,\eta)$ expression in F rectangle sides median points, and σ_2 – is the value of $f(\xi,\eta)$ expression in F rectangle center.
Due the calculation upper limit of load bearing capacity for plates will be as

$$P_{pl} = 54.347\frac{h^2\sigma_{xx}}{3e^2}\ kg/cm^2$$

When the shell is performed with taking into account the intermediate hinges (Fig. 2)

In this case the derivatives of deflection function ω(ξ,η) are subjected to break due that for finding of kinematical allowable deflections filed let's apply the discontinuous solution construction method of equation (10) that in this general case will have direction "x" [13-16].

$$EY\omega(\xi) = EY\left[\omega(o) + \xi\dot{\omega}(o) + \sum_m^{\xi} A_m + \sum_r^{\xi} B_r(\xi - a_r)\right] + M_0\frac{1}{2} + Q_0\frac{1}{6} +$$

$$+\frac{1}{2}\sum_k^{\xi} m_k(\xi - a_k)^3 + \frac{1}{6}\sum_\rho^{\xi} P_\rho(\xi - a_\rho)^3 + \frac{1}{6}\int_0^{\xi}(\xi - t)^3 q(t)dt, \qquad (14)$$

where A_m, B_r, m_k, P_p, are the values of $\omega(\xi)$ function and its derivative, and a_r, a_r, a_p are the accordingly first, second and third order derivatives break points.
In the longitudinal direction at existing of one break point in center the expression (14) will be as:

$$EY\omega(\xi) = M_0\frac{\xi^3}{2} + Q_0\frac{\xi^3}{6} + EYB_1\left(\xi - \frac{1}{2}\right) - q\frac{\xi^4}{24}. \tag{15}$$

In case when elements of prefabricated shell are connected by longitudinal as well as transverse hinges due yet obtained formulae in “x’’ direction for values of deflection we will have

$$when\ \xi < \frac{1}{2} \quad \omega_1(\xi) = C_1(-3\xi^2 + 4\xi^4 - 2\xi^4) \tag{16}$$

As it is obvious from the obtained results it is related on number of prefabricated elements. For obtaining of shell load bearing capacity to plate load bearing capacity will be added dependent of radius of curvature the following constant value

$$\frac{2h\sigma_{xx}}{\sqrt{3}}\left(\frac{1}{R_1^2} + \frac{1}{R_1R_2} + \frac{1}{R_1^2}\right)^{1/2}.$$

3. CONCLUSIONS

At research of elastic-plastic equilibrium of shell type prefabricated structures due discontinuous solutions and variation equations of equilibrium are obtained relations between deformations and loadings.

Are developed the variants of application of discontinuous solution of prefabricated structures. Are analyzed the impact of complete and incomplete hinges on mode of deformation of structure. Is researched the dependency of load bearing capacity of structure on number of constituent elements.

BIBLIOGRAPHY

Savchuk A.O. *On plastic analysis of shells. Mechanics of deformable solids: Directions of development.* Moscow. 1983, pp. 274-309.

Lekhnitski C.G. *Theory of elasticity of anisotropic solid*. Moscow: 1977, -415 p.

Beliaev N.M., Sinitski A.K. *Stresses and deformations in thick-walled cylinders at elastic-plastic state of material with consideration of strengthening.* Transactions of Academy of Sciences of USSR. OTN, 1938, № 4, pp. 21-49.

Shapiro R.S. Impact on ring rigid-plastic plate. PMM, 1959, V. 23, is. 1, pp. 172-175.

Tskvedadze R.M. *Assessment of depressed prefabricated shell load bearing capability.* Georgian Engineering News, Tbilisi, № 2, 1999, pp. 23-25.

Olshak V., Savchuk A. *Non-elastic behavior of shells*. Translation from Eng.. Under editorship of G.S. Shapiro. Moscow: Mir, 1969. -144 p.

Ilushin A.A. Plasticity. Moscow-Leningrad: Gostekhizdat, 1949. -438 p.

Rabotnov Yu.N. *Approximated technical theory of elastic-plastic shells.* PMM, 1951, V. 15, is. 2, pp. 167-174.

Mikeladze M.Sh. *Introduction in technical theory of ideal-plastic thin shells*. Tbilisi: Metsniereba, 1969. -182 p.

Mikeladze Sh.E. *Some tasks of structural mechanics.* Moscow-Leningrad:1948. -269 p.

Mikhailov B.K., Kipiani G.O. *Deformability and stability of spatial plate systems with discontinuous parameters.* Saint Petersburg: Stroyizda, SpB, 1996. -442 p.

Tskvedadze R.M., Kipiani G.O., Beridze T.Sh., Pailodze N.R. *Optimal design of metal plates and shells with application of continuous heterogeneous materials*. International Scientific Journal of IFToMM “Problems of mechanics”, Tbilisi, № 3(20), 2005, pp. 70-75.

Kipiani G., Pailodze N. *The condition of rectangular plates with rectangular cuts in intense-deformed state*. International Scientific Journal of IFToMM “Problems of mechanics”, Tbilisi, № 3(20), 2005, pp. 14-18.

Kipiani G. *Design procedure on stability of three-layered plate with cuts and holes.* Georgian International Journal of Science and Technology, Vol. 1, № 4, Nova Publishers, New York, 2008, pp. 317-342.

Kipiani G., Churchelauri B., Churchelauri Z. *determination of critical loading at mode of deformation of having rectangle cut structures*. International Scientific Journal of IFToMM “Problems of mechanics”, Tbilisi, № 1(58), 2015, pp. 72-75.

Kipiani G., Rayczyk M., Lausova L. *Influence of rectangular holes on stability of three-layered plates*. Applied Mechanics and Materials, Vol. 711(2015), pp. 397-401. ©(2015), Trans. Tech. Publications, Switzerland. Doi:10.4028/www.scientific.net/AMM.711.397.

STRUCTURE STYLE SELECTION OF THE MID-TOWER OF A THREE-TOWERSUSPENSION BRIDGE

POSTER

Jun Dong[1], Jiangxiao Feng[2], Tian Liang[3]
Beijing Research Center for Engineering Structures and New Materials,
Beijing University of Civil Engineering and Architecture, China
email: [1] jdongcg@bucea.edu.cn, [2] 949114243@qq.com,[3] liangtain1630@163.com

Keywords

three-tower suspension bridge, mid-tower, finite element analysis

ABSTRACT

Three tower suspension bridge is a new bridge system, the design of the mid-tower is the key of the whole design of suspension bridge, the longitudinal form of the tower has great effect on the static and dynamic characteristics. Based on the analysis of the Ma'anshan Bridge, a three-tower suspension bridge, the suitable structure form of the mid-tower were analyzed, such as the deflection of the main span and the ant-i slipping safety factor between the main cable and saddle of the mid-tower. I type steel tower, I type steel concrete combined column, herringbone structure tower are analyzed. The analysis based on the finite element method shows that the I type steel concrete combined column and herringbone structure are appropriate. The relevant research results are significant for the design of the similar bridge structure.

INTRODUCTION

Three tower suspension bridge is a new bridge system, compared with the two tower suspension bridge, three tower suspension bridge with main span more than one and one tower, because of this, the static and dynamic characteristics of suspension bridge with two towers are different. Although the three tower suspension bridge has attracted great attention of scholars, and made a lot of research work, but in the research on the tower is not deep enough overall, while the longitudinal beam form tower tower connection mode and the tower has great effect on the static and dynamic characteristics, the article researches the connection according to the tower with the tower and beam method and tower longitudinal form different selected six tower plan, as follows:

1, the longitudinal I shaped steel-concrete composite column scheme, namely Ma'anshan bridge prototype scheme in the tower, the height is 178.8 meters , the horizontal for the door type frame structure, two transverse center spacing between tower, tower 35 meters, the bottom of the tower is 43.5 meters, the middle is provided with two beams. In columns that are divided into two parts: the upper 127.8 meters from adopts full steel tower, under paragraph 40.5 meters using concrete tower, tower 10.5 meters high decoration period, by the tower girder consolidation system.

2, the longitudinal I shaped steel tower in the whole scheme, 178.8 meters high tower wide, lateral to the portal frame structure, two transverse center spacing between tower, tower 35 meters, the bottom of the tower is 43.5 meters, the middle is provided with two beams. Tower transverse size is 6 meters, the longitudinal dimension from the top surface to the bottom of the tower 7 meters changes by 17 meters, tower beam consolidation system.

3, the longitudinal for the humanoid full steel tower scheme, combining with the results of existing bridge in Taizhou, this paper determines the tower up to 178.8 meters in the model, the herringbone tower two oblique leg center line intersection of elevation is above 52.4, the intersection point of intersection of the tower 123 meters high, tower 45.3 meters high, the top decoration section of 10.5 meters high, two oblique legs splayed volume at the bottom of the tower is 30 meters, using tower girder consolidation system.

4, the longitudinal I shaped steel-concrete composite column scheme, namely Ma'anshan bridge prototype scheme, only in the tower between the tower and beam longitudinal match with stiffness of 1000000kN/m elastic cable, tower on each side of a total of two, as, tower and beam separation system.

5, the longitudinal I shaped steel tower in the whole scheme, 178.8 meters high tower wide, and 2 the same, just in the tower between the tower and beam longitudinal match with stiffness of 1000000kN/m elastic cable, tower on each side of a total of two, as, tower and beam separation system.

6, the longitudinal for the humanoid full steel tower scheme, and the 3 the same, just in the tower between the tower and beam longitudinal match with stiffness of 1000000kN/m elastic cable, tower on each side of a total of two, as, tower and beam separation system.

This paper considered under live load, the six schemes on the displacement and internal force of girder, tower Bi-anta displacement and internal force, displacement and internal force of main cable, anti slip and other differences, in-depth analysis for three tower suspension bridge in tower form.

1 EFFECT OF DIFFERENT FORMS OF TOWER IN THE STATIC PERFORMANCE OF STRUCTURE

1.1 The displacement and internal force of main girder

In the suspension bridge system, the main beam is very important component of three tower suspension bridge, the whole rigidity than two tower suspension bridge down a lot, so the nonlinear displacement is significant, large deformations occur under vehicle load, in order to ensure the normal operation of the bridge, the displacement and internal force response analysis of bridge under vehicle load, to ensure the safety of structure. Analysis of girder displacement are as follows:

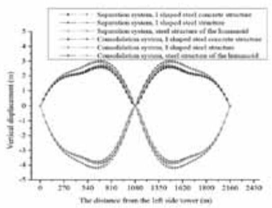


Fig.1-1 The vertical displacement of stiffening girder under different forms of middle tower

Table 1-1 The stiffening girder displacement values under different forms of tower

The form of the tower		Maximum deflection	Maximum upward displacement	Maximum displacement of beam end	Maximum angle
Tower beam consolidation system	I shaped steel-concrete	-3.763	2.566	0.051	0.017
	I shaped steel tower	-4.147	2.928	0.126	0.017
	Humanoid tower	-3.822	2.622	0.052	0.017
Tower beam separation system	I shaped steel-concrete	-3.858	2.686	0.099	0.017
	I shaped steel tower	-4.217	3.019	0.173	0.017
	Humanoid tower	-3.912	2.736	0.101	0.017

As can be seen, consolidation system, I shaped steel girder structure system of mixed all the values are smaller, followed by the humanoid tower structure, the biggest is I shaped steel structure, I shaped steel concrete structure, steel structure of the humanoid maximum deflection and the maximum upward displacement are I shaped steel tower structure 90.7% 87.6%, 89.5%, and 92.2. I shaped steel concrete structure, steel structure of the humanoid maximum deflection and the maximum upward displacement difference of 1.6%, 2.2%, basically equivalent. From the beam end displacement, I shaped steel concrete structure, steel structure gap is humanoid, and I shaped steel structure of the beam end shift compared with the other two system increase by nearly 2.5 times, up to 0.126m; the end of the beam angle of the three 0.017rad. Separation system, the I profile steel girder structure system of mixed all the values are smaller and the second is the humanoid tower structure, the biggest is I shaped steel structure, I shaped steel concrete structure, steel structure of the humanoid maximum deflection and the maximum upward displacement of I shaped steel tower structure respectively 91.4%, 88.9% and 92.7%, 90.6%. I shaped steel concrete structure, steel structure of the humanoid maximum deflection and the maximum upward displacement difference of 1.3%, 1.8%, the gap is very small. From the beam end displacement, I shaped steel concrete structure, steel structure gap is humanoid, and I shaped steel structure of the beam end shift compared with the other two system increase nearly 1.7 times, reached 0.173m, beam end displacement of large, the system is unfavorable to the stress in beam end rotation; three are 0.017rad, can not see the obvious influence on beam end corner tower form. Overall, the consolidation of the values were smaller than the main beam under the system of separate systems, especially the beam end displacement, separation system is almost 2 times the consolidation system.

Analysis of girder moment are as follows:

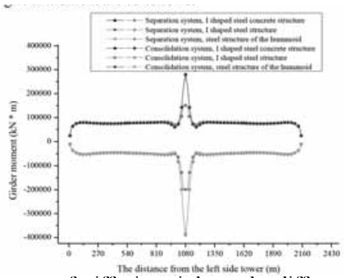


Fig.1-2 The bending moment of stiffening girder under different forms of middle tower

Table 1-2 Bending Moment under Different Forms of Tower

Bending Moment	I shaped steel- concrete (kN*m)		I shaped steel tower(kN*m)		Humanoid tower(kN*m)	
	The maximum value of consolidation system	The maximum value of separation system	The maximum value of consolidation system	The maximum value of separation system	The maximum value of consolidation system	The maximum value of separation system
L/4	76280.26	76430.87	76567.11	76724.91	76309.74	76461.86
L/2	77139.85	77199.1	77750.92	77822.18	77221.09	77284.34
3L/4	80536.12	79898.41	81225.92	80543.71	80668.46	80020.45
Mid-tower	389270.94	202199.55	383930.46	202247.81	387804.58	202169.6
The Maximum Stress (MPa)	88.3	68.1	86.9	68.1	87.8	68.1

As can be seen, consolidation system, L/4 at the moment from the I shaped steel concrete combined column to steel tower to humanoid I shaped steel tower becomes larger, but the difference is not big, mid span moment and 3L/4 moment changes also follow the same rules, the numerical difference is not large; at the moment of tower and variation of the I shaped steel tower structure is different, the minimum, followed by the humanoid steel structure, I shaped steel concrete structure maximum, I shaped tower steel structure and steel structure in the moment of humanoid are I shaped steel concrete structure in 98.5% and 99.6%, I - shaped bending steel tower structure is humanoid tower 98.9%, the gap is very small. Tower beam separation system changing rules of the stiffening girder moment and consolidation of the same system, but can be clearly seen from the consolidation system under the moment ratio separation system under large nearly 2 times, the corresponding stiffening girder maximum stress value is also nearly 30% separation system under the big, but still less than the allowable value of 203MPa stress stiffening girder this is because the tower, girder consolidation system stiffening Liang Jiagao tower is 5 meters, on the whole, the six scheme had little difference.

Through the above analysis, from the stiffening girder internal force and displacement angle, I shaped steel mixed the whole performance of the structure better.

1.2 The displacement and internal force of Mid-tower

In the three tower suspension bridge system, design of tower is the key, the displacement and internal force of tower is very important to the whole suspension bridge, under vehicle load, in the tower will shifts, significantly affect the stress and deformation of stiffening girder, tower displacement and internal force analysis of different form below table, axial force bending moment kN as unit, unit kN*m, displacement for m units:

As can be seen from the table in 1-3, in the action of live load, the axial force of steel structure section is the largest of the humanoid steel structure, structure and I - the maximum axial force of tower structure of basic quite mixed I shaped steel, the maximum axial force of humanoid tower about 5 times as much as the other two kinds of structure; steel structure section bending moment the small humanoid steel tower, the second is I shaped steel concrete structure, the maximum is I shaped steel tower structure, on the whole, the maximum bending moment is I shaped steel concrete structure, I shaped steel concrete mixed structure section stress values in the column beam consolidation and tower beam separation system difference, the maximum value appeared in the binding site of the steel tower and concrete tower, the tension stress can be configured through the control of prestressed steel structure section within 1.83MPa, maximum stress value is 231.7MPa, the corresponding materials does not exceed the allowable stress of 240MPa, the maximum value appeared in the steel tower and concrete tower binding site;I shaped steel tower and the tower of the humanoid maximum tensile and compressive stress difference, which does not exceed the allowable stress of 240MPa, the maximum value appeared in the tower and beam near the binding

Table 1-3 The displacement and internal force of Mid-tower

	I shaped steel- concrete		I shaped steel tower		Humanoid tower	
	Maximum value of consolidation system	Maximum value of separation system	Maximum value of consolidation system	Maximum value of separation system	Maximum value of consolidation system	Maximum value of separation system
Axial force of steel structure	-21349.38	-21336.43	-21349.09	-21336.19	-107119.42	-104963.92
Axial force of concrete segment	-21349.38	-21336.43	--	--	--	--
Bending Moment of steel structure	1966291.2	-1903933.7	2483216.9	2441991.94	1675511.42	1786329.22
Bending Moment of concrete segment	-2690597.63	-2640456.45	--	--	--	--
Maximum tensile stress of concrete segment	3.4	3.3	--	--	--	--
Maximum compressive stress of concrete segment	-6.8	-6.5	--	--	--	--
Maximum tensile stress of steel structure	133.1	125.6	115.6	109.3	95.7	103.8
Maximum compressive stress of steel structure	-231.7	-228.9	-222.5	-219.6	-222.3	230.4
The top displacement	1.374	1.451	1.657	1.722	1.416	1.49

site; from the tower top displacement, consolidation system of I shaped steel concrete structure displacement minimum 1.374m, I shaped steel structure is the largest tower beam separation system, 1.722m. In general, the structure stress better mixed I shaped steel, in moderate stiffness

1.3 The displacement and internal force of Side-tower

The car loads, follows a different form of tower in tower bottom displacement and internal force analysis of axial force, bending moment of the unit is kN, the unit is kN * m, displacement for m units:

Table 1-4 The displacement and internal force of Side-tower

	I shaped steel- concrete		I shaped steel tower		Humanoid tower	
	Maximum value of consolidation system	Maximum value of separation system	Maximum value of consolidation system	Maximum value of separation system	Maximum value of consolidation system	Maximum value of separation system
Axial force	-19525.26	-19554.96	-19516.96	-19543.71	-19524.72	-19554.04
Bending Moment	200605.15	200968.51	200392.82	200735.81	200583.17	200943.9
Maximum stress	-15.2	-15.2	-15.2	-15.2	-15.2	-15.2
The top displacement	0.161	0.161	0.161	0.161	0.161	0.161

As can be seen from the table, six schemes of tower axis below the maximum stress difference, can be ignored; Bianta maximum moment not quite, section stress was compressive stress, and the value is equal to 15.2MPa, no more than the specification requirements of the 22.4MPa, no tensile stress, and the top displacement are equal, for the 0.161m; the maximum values appeared at the bottom of the tower and stress bending moment, from the table can be seen in the form of Bianta effect of tower displacement and internal force is very small.

1.4 Main cable safety factor against sliding

The main cable is an important bearing component of suspension bridge, and its stability directly related to the safety of the bridge, the main cable in between and at the top of the tower saddle anti sliding stability is the key issue, in the three tower suspension bridge system, when a cross loaded and another cross no-load main cable saddle, both sides have a big cable force is poor, if not will produce friction slip, causing the disintegration of the entire system failure, so for three tower suspension bridge tower, requirements in any condition, ensure the main cable without relative slip in the main saddle are to, to ensure that the main cable anti slip safety coefficient reaches the requirement, live load different forms of main cable tower under the anti slip as shown in the following table, the internal force calculation method of unit kN, the front of anti sliding safety factor has been described, here no longer:

Table 1-5 The inter force of main cable of the middle tower and anti-slip safety factor coefficient

The form of the tower		Tight side force	The loose side force	Internal force difference	Safety coefficient	The allowable value
Tower beam consolidation system	I shaped steel-concrete	199304.3	185395.5	13908.8	2.31	≥2
	I shaped steel tower	198604.3	186084	12520.3	2.57	≥2
	Humanoid tower	199187.5	185510.1	13677.4	2.35	≥2
Tower beam separation system	I shaped steel-concrete	200282.6	184627.1	15655.5	2.06	≥2
	I shaped steel tower	199522.9	185355.1	14167.8	2.27	≥2
	Humanoid tower	200154.3	184748.8	15405.5	2.09	≥2

As can be seen from table 1-5, different forms of tower of the main cable anti slip stability influence or larger, consolidated system under the I shaped steel concrete structure on both sides of the difference between the maximum cable force, the second is the humanoid steel structure, I shaped tower cable force in both sides of steel tower structure difference between the minimum safety factor, corresponding to the contrary, I shaped steel the minimum factor of safety of mixed structure, followed by the humanoid I shape steel tower structure, tower structure of the highest safety factor, which reflects the I shaped steel mixing in the tower of the maximum stiffness, I shaped steel tower of minimum stiffness. Tower beam separation system and the consolidation of the same system, I shaped steel concrete structure safety coefficient is the smallest, next is the humanoid tower structure, the biggest is I shaped steel structure, but the safety coefficient of consolidation of pylon beam system is higher than that of the tower and beam separation system. Anti slip from the situation, the six scheme satisfies the requirements of.

2 CONCLUSIONS

Through the above six kind of scheme comparison of static characteristics, six kinds of schemes can satisfy the key control parameters of three tower suspension bridge main cable requirements, namely, anti sliding safety factor is greater than 2, the maximum vertical deflection value is not greater than the span of 1/250 ~ 1/300, the Liang Duan rotation angle of not more than 0.02rad, the conclusions are listed as follows:

(1) from the stiffening girder internal force and displacement angle, consolidation system under the I shaped steel mixed structure better overall performance.

(2) from the tower of the displacement and internal force of point of view, consolidation system under the I shaped steel mixed structure better overall performance.

(3) influence on the displacement and internal force of tower form Bianta is very small.

(4) from the anti slip, tower girder consolidation system is superior to the tower and beam separation system.

Through the above on the static and dynamic characteristics of six kinds of different forms under the tower in contrast, structure and human tower structure stress better mixed I shaped steel, I shaped steel concrete structure of the overall stiffness is slightly larger than the humanoid tower structure, tower girder consolidation system good stress.

REFERENCES

[1] C.J. Younis,D.E. Panayotoukos. *Analytical Solution of the Dynamic Response of Suspension Bridge Tower–Pier Systems with Distributed Mass to Base Excitation*.Journal of Sound and Vibration,2000, Pages 467–490

[2] Steinman,D.B. *Modes and natural frequencies of suspension bridges oscillations.* Journal of the Franklin Institute.1959

[3] W.-X.Ren,G.E.Blandford,I.E.Harik. *Roebling suspension bridge. I:Finite-element model and free vibration response*.Journal of Bridge Engineering.2004

[4] Abdel-Ghaffar,A.M.,tringfellow,R.G. *Response of suspension bridges to travelling earthquake excitations:Part i*.Vertical response. Soil Dynamics and Earthquake Engineering.1984

[5] Abdel-Ghaffar,A.M.,Rubin,L.I.*Response of suspension bridges to traveling earthquake excitations:Part II*.Lateral response. Preprints-1982 ASCE National Convention.1984.Las Vegas,NV,USA:ASCE.

[6] Abdel-Ghaffar,A.M.,Rubin,L.I.*Torsional earthquake response of suspension bridges*.Journal of Engineering Mechanics.1984,110(10)

[7] Dumanoglu,A.A.,R.T.Severn. *Seismic response of modern suspension bridges to asynchronous vertical ground motion*.Proceedings of the Institution of Civil Engineers. 1987.London.

[8] Dumanoglu,A.A.,R.T.Severn. *Seismic response of modern suspension bridges to asynchronous longitudinal and lateral ground motion*.Proceedings of the Institution of Civil Engineers. 1989.London.

[9] FORSBERG T, PETERSEN A. *The challenge of constructing a bridge over the Chacao Channel*[C]MIABSE: IABSE Conference on Cable-Supported Bridges-Challenging Technical Limits. Zurich: IABSE, 2001: 1-8.

[10] SATO K. *Deflection theory of multi-span suspension bridges considering deflection of towers and its numerical examples of various influence lines*[J]. Proceedings of Japan Society Civil Engineering, 1971, 19(1):11-22.

STUDY OF LOW-CARBON AND LOW-ALLOY STEEL RECRYSTALLIZATION WITH THE USE OF PASSIVE FLUX-GATE TEST METHOD

Valery Gordienko[1], Elena Smirnova[2]
St. Petersburg State University of Architecture and Civil Engineering, Russia
email: [1]npd@spbgasu.ru, [2]esmirnovae@yandex.ru

Keywords

cold plastic deformation, materials technology, non-destructive testing

ABSTRACT

A lot of attention is paid in Russia to the advanced developments in the field of metallurgical technologies and application thereof in different fields. The most acceptable method of providing the fine-grain structure is the recrystallization annealing. The main purpose of annealing is to build a uniform structure providing for better workability of steel products and higher level of mechanical properties thereof. It becomes possible as a result of recrystallization in solid state to correct such a significant defect of steel structures as the coarse-grained structure obtained as a result of overheating. The possibilities of passive flux-gate test method have been studied to check shaping the fine-grained structure in the course of recrystallization annealing. A correlative relationship has been revealed between the temperature of heating and structural changes taking place on the cold-worked low-carbon 08ps and low-alloy 09G2S and 10HSND steels.

1. INTRODUCTION

Presently, there is no universally accepted theory of recrystallization at annealing. Both the recrystallization kinetics and the theory of the recrystallization centers forming are insufficiently investigated. In this connection the relevancy and unlikelihood of the above subject are beyond all doubts. There is a need for further new substantial approaches and assumptions. Paying special attention to the experimental results the authors see the purpose of this article in substantiating emergence of the fine-grain structure in the structural low-tempered steel after recrystallization annealing.

2. BACKGROUND

The main purpose of annealing is the formation of a homogenous steel structure providing for better workability of articles and higher level of mechanical properties. As a result of recrystallization in solid state it becomes possible to correct such an existing defect of the steel structures as the coarse-grain structure obtained as a result of overheating. In this connection the possibilities of passive flux-gate test method have been studied to check for shaping the fine-grain structure in the process of recrystallization annealing.
Thus, the introduction of alloying elements incre ases mechanical properties of the steel and, in particular, reduces the threshold of cold brittleness. In case of grain grinding the strength of hardened low-tempered steel increases, i.e. increases its yield point, yield stress at various deformation values, ultimate strength, hardness and fatigue strength. As a result, a possibility will appear to reduce the weight of structures, ensure required reliability and durability thereof.

3. METHODS

The following were chosen for experimental research: low-carbon steel 08ps and low-alloy steels 09G2S and 10HSND.
This choice was conditioned by the fact that these steels:

• are widely used in various industries;
• have good plasticity characteristics in the field of both standard and low temperatures;
• allow expanding the obtained regularities to all materials with similar composition and properties, and giving substantiated recommendations for them.

In order to carry out investigations the plates 30 mm wide, 150 mm long and 2 mm thick have been cut out of the sheets of structural steels 08ps, 09G2S and 10HSND across the rolling direction that have been subject to fractional cold plastic deformation to a degree =50% (, [epsilon] □ degree of plastic deformation). The samples have been cut out of these plates for subsequent recrystallization annealing at temperatures of 20°C to 800°C and conducting metallographic examinations. Apart from this, in order to assess the influence of equilibrium structure on the magnetic properties of steels, some samples have been subjected to high-temperature annealing at 900°C and 1050°C after the cold plastic deformation.

The beginning and end of recrystallization have been determined by passive flux-gate test method through measuring the strength of stray magnetic fields (Hp) at the tested samples by means of stress concentration magnetometric gauge with dual-channel flux-gate test transducer and by means of microstructural analysis.

4. CASE HISTORY

In the course of steels structure investigation the problems appear that are related to insufficient clarity of recrystallization kinetics (Bhadeshia, H. & Honeycombe, R. 2007; Callister, D.W. & Rethwisch, D.G. 2010; Lobanov, L.M. et al. 2006). One of them concerns an issue, whether the metals get crystallized in the course of deformation or in the wake of hot deformation? According to us a significant reduction of Hp values at temperatures from 150°C to 300°C (Figure 1) is probably related to the course of the first stage of return, the rest, in steels. As a result of the rest, a number of pin hole defects (interstitial atoms and vacancies) gets reduced through annihilation at the edge dislocations. The number of distortions of crystalline lattice also drops.

According to Shackelford & Alexander (2001) no structural adjustments of dislocation structure take place in this case. We suppose that in case of increasing the temperature of heating in excess of 300°C the reduction of Hp values happen due to diffusion processes activation. At that, redistribution of dislocations, annihilation thereof and forming-up excessive dislocations of the same sign into vertical dislocation walls occur, which results in subgrains formation: the polygonization process is in progress. According to Montheillet (2005) they become larger due to dislocation boundaries movement, which brings about the reduction of defects density.

As it was stated before, the kinetics of recrystallization and formation of recrystallization centers provokes many questions due to insufficient knowledge about it. It is considered that recrystallization begins normally at the boundaries of grains at increasing the temperature of annealing. Hence, the presence or absence of recrystallization depends basically on the energy of deformation of the boundaries of grains required for origination of new grains (Panov, D.O. et al. 2013).

However, such a finding needs clarification. We suppose that the beginning of primary recrystallization is characterized by the formation of recrystallization centers in those areas of deformed grains, where the density of dislocations is increased and the crystalline lattice features the worst distortions (Gordienko, V. 2013). They grow as a result of reattachment (diffusion) of atoms thereto from a deformed environment, at that, the boundaries of recrystallization center migrate towards the deformed environment. It should be noted that according to data of metallographic research carried out by the authors the beginning of recrystallization for steel 08ps is observed at 550°C, while for steels 09G2S and 10HSND it is observed at 600°C. In case of magnetic testing not only the recrystallization beginning gets recorded but the return processes as well, which testifies to high sensitivity of the magnetic method.

5. RESULTS

Fig.1 shows a dependence of the magnetic field strength on the temperature of recrystallization annealing for steels 08ps, 09G2S and 10HSND.

Fig.2 presents a change of structure of steels under study 08ps, 09G2S and 10HSND after recrystallization annealing at 900°C and 1050°C.

Fig.3 shows variation of structure of steel 08ps during recrystallization annealing.

Fig.4 shows variation of structure of silicon-manganese-based steel 09G2S after recrystallization annealing.

As Figure 1 shows a sharp reduction of magnetic field strength (Hp) values for all steels under study is observed

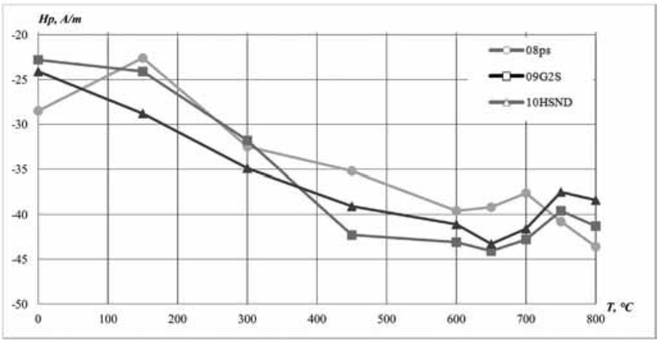


Fig. 1. Dependence of stray magnetic field Hp strength on temperature of recrystallization annealing for steels 08ps, 09G2S and 10HSND.

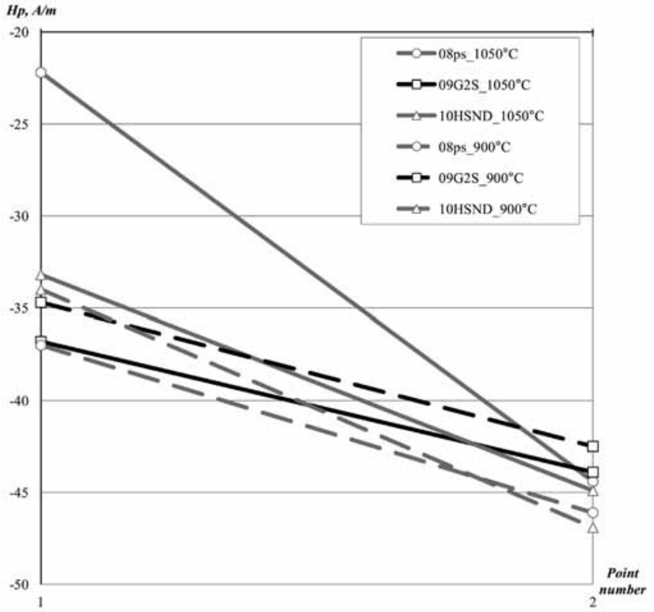


Fig. 2. Variation of stray magnetic field Hp strength in samples of steels 08ps, 09G2S and 10HSND after annealing at 1050oC (continuous line) and 900oC (broken line) axis: 1 – before annealing, axis 2 – after annealing.

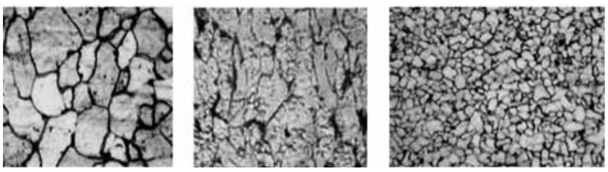


Fig. 3. Variation of structure of steels 08ps during recrystallization annealing, x400:
a – as-delivered state, b – after rolling at =50%, c – after annealing at 700°C.

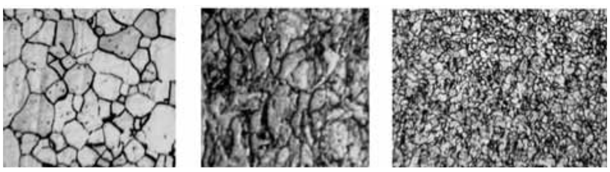


Fig. 4. Variation of structure of steels 09G2S during recrystallization annealing, x400:
a – as-delivered state, b – after rolling at =50%, c – after annealing at 725°C.

in the range of temperatures from 150°C to 300°C. As the heating temperature rises in excess of 300°C, a further reduction of Hp values takes place but with lower intensity. The reduction of Hp values stops in the range of temperatures from 600°C to 650°C and then a certain rise can be observed.

The increase of temperature of annealing for the deformed steel from 900°C to 1050°C changes the value of Hp as compared with the original state (Figure 2). At that, the increase of annealing temperature irrespective of the steel grade, contributes to stabilizing Hp values and approximating them to the values commeasurable with the strength of magnetic field of the Earth (±40 A/m= 0.5 Gs).

According to data of metallographic investigation the beginning of recrystallization for steel 08ps is observed at 550°C, for steels 09G2S and 10HSND it is observed at 600°C. The temperature of recrystallization end for steel 08ps at 700°C (Figure 3), for 09G2S and 10HSND – at 725°C (Figure 4). The fine-grain structure with grain size of 8 □m for steel 08ps, 6 □m for steel 09G2S and 5 □m for steel 10HSND is shaped in the process of primary recrystallization. Further increase of annealing temperature brings about an increase of grains size. It should be noted that as the degree of steel alloying, increases, more fine-grain equiaxed structure is shaped, which ensures isotropy of mechanical properties (Campbell, F.C. 2008).

6. CONCLUSIONS

The study of recrystallization of low-carbon and low-alloy steels 08ps, 09G2S and 10HSND helps come to the following conclusions:

1. Preliminary cold plastic deformation and the subsequent recrystallization annealing are the most acceptable methods of obtaining the fine-grain structure in low-carbon and low-alloy structural steels.

2. Registration of quite an early stage of finishing the primary recrystallization in structural steels 08ps, 09G2S and 10HSND makes it possible to attain the fine-grain equiaxed structure, which becomes more particulate in the course of increasing the degree of alloying.

3. At that it is possible to use rather high sensitivity of the stray magnetic field (Hp) strength depending on the temperature of recrystallization annealing for checking quality of low-carbon and low-alloy steels.

BIBLIOGRAPHY

Bhadeshia, H. & Honeycombe, R. (2007). *Steels: Microstructure and properties*. 3rd Edn. Amsterdam: Elsevier.

Callister, D.W. & Rethwisch, D.G. (2014). *Materials science and engineering: An introduction*. 9th Edn. Hoboken: Wiley.

Campbell, F.C., 2008. *Elements of metallurgy and engineering alloys*. Materials Park: ASM International.

Lobanov, L.M., Kyr'yan, V.I. & Knysh, V.V. (2006). *Enhancement of the service life of welded metal structures by high-frequency mechanical peening*. Materials Science, 42(1), 54–60.

Shackelford, J.F. & Alexander, W. (2001). *CRC materials science and engineering handbook*. 3rd Edn. Boca Raton: CRC Press.

Montheillet, F. (2004). *Moving grain boundaries during hot deformation of metals: Dynamic recrystallization*. In F.D. Fischer (Ed.), *Moving Interfaces in Crystalline Solids* (pp. 203–256). Wien: Springer.

Panov, D.O., Simonov, Yu.N., Leont'ev, P.A. et al. (2013). *A study of phase and structural transformations of hardened low-carbon steel under conditions of multiple intense heat effect. Metal Science and Heat Treatment*, 54(11–12), 582–586.

Gordienko, V. (2013). *Investigation of influence by the cold plastic deformation of metals on magnetic intensity of scattering*. World Applied Sciences Journal, 23(13), 74–79.

EVALUATION OF TECHNOLOGY APPLYING LIMESTONE POWDER IN ROAD PAVEMENT LAYERS

Hakob Gyulzadyan[1], Vigen Ter-Simonyan[2] , Gevorg Voskanyan[3]
National University of Architecture and Construction, Armenia
email: [1]hakob_gyulzadyan@bk.ru, [2]ardvigen@mail.ru, [3]1713gevorg@mail.ru, www.nuaca.am

Keywords

road construction, travertine powder, road pavement

ABSTRACT

This paper presents a new technology of strengthening road pavement layers from crushed-stone-gravel-sandy mixtures, based on applying waste materials of limestone mines. Testing were done for development parameters of technology. Additional testing were carried out for profitability assessment of applying travertine powder in layers from crushed stone-sand mixtures. Applying travertine powder at optimum percentages in C6 crushed-stone-gravel-sandy mixtures with crushed basalt and crushed gravel sand are equal to applying cement at percentage respectively 3.5% and 2.5%.The suggested technology was introduced with comparative tests of experimental road sections, with simultaneous assessment of the change of rigidity of the road pavement layer. Field testing showed the values of elasticity modulus of C6 mixture and of the new mixture, created by mixing C6 mixture with travertine powder in optimal quantity.

1. INTRODUCTION

The development of road network is one of actual problems in Republic of Armenia. It is based on two important ideas – to increase road construction quality and to enlarge the road network. Requirements to road network are rising due to development of country economy. In consideration of actual conditions, design and construction of durable and resistant road pavements is a way to satisfying current requirements.

Mixtures of aggregates with optimal granulometric composition are widely used in road construction practice, especially in road pavement layers. An example are crushed-stone-gravel-sandy optimal mixtures (hereinafter referred to as ready mixtures), which are used during the recent years also in Republic Armenia's road construction, mainly as base and subbase layers of pavement. However, along with comparatively cheap price, the layers, made from the mentioned material, do not always have the required strength and service life, and the problem of their strengthening with relatively less costly means becomes urgent. Taking into account the high cost of organic and inorganic binders, for the restoration of local roadnet pavements can be applied the strengthening of ready mixtures with the use of various stone powders or industrial wastes. In particular, it is economically perspective to use travertine powder as an additive in ready mixtures, which is available in sufficient quantity especially in Ararat region. Hence, the paper underlines the purpose of developing technology of ready mixtures with optimal granulometric composition, made on the basis of travertine powder, which will ensure high performance of base and surface courses, made from these mixtures, as well as their introduction into the practice of road construction and repair.

2. BACKGROUND

30-ies of the last century began soil stabilization feature have been used in the local roads construction. The practice of reducing volume requirements of construction stone materials and replacing them with strengthened soils for road pavements construction has promoted development of soil treatment technologies and creating more effective variants in UK, USA and European countries. Using of modified and treated soils and aggregates in road pavements layers has been checked by time, and has started applying widely especially in USA (Sherwood Ph. 1995).

Organic and mineral binders are used for strengthening and treatment of soils and aggregates. Strengthening soils and aggregates with mineral binders – cement and lime, are widespread options. Along with the application of mineral or inorganic, organic binders’ use is also widespread. There are many technologies of soils strengthening with complex method, using different types of binders simultaneously. Cement and bitumen mainly are used for complex strengthening of soils and aggregates, different surface-active and structure-forming materials – lime, fly ash, gypsum, other chemical materials are used as additives. The main feature of complex strengthening is to modify the physicomechanical and physicochemical properties in wide range of positive direction by exact selecting binders and their optimal quantity, to increase adhesion properties of binders, to accelerate or decelérate the binding process in strengthening soils.

Different type of industrial wastes are widely used in road pavement layers in many countries. For example, fast hardening mixtures are applying for construction local roads with soil surface in Russia. Water resistant gypsums are used as an additional binders, which are formed from industrial wastes, especially generated during wet magnetic separation of iron quartz. The wastes of metallurgy industry and electrometallurgy are widely used in road bases construction. The new reagent has been developed for decreasing dust formation, which is based on sulphide and limestone powder (Motovilov B.P. 1984).

The big practice of applying industrial wastes in local road pavement layers from aggregate mixtures was formed in India (Tara S., Umesh M. 2010). Realization of industrial wastes and environmental protection are urgent problems for India. Industrial wastes are fly ash, blast furnace dust, cement kiln dust, phosphogypsum, waste plastic bags and foundry sand and colliery sand.

Big amounts of travertine powder, which is industrial waste, was accumulated in travertine or limestone mines of Republic of Armenia. We have done studies for applying travertine powder as an additive-binder in road pavement layers of ready mixtures.

3. METHODS

Laboratory testing have been done for identifying optimal quantities of adding travertine powder as an additive into the composition of ready mixtures, evaluation of strength indexes of mixtures with travertine powder, determining of effectiveness adding travertine powder in mixtures. Testing have been done according to current state standards and other regulatory documents. Especially, physicomechanical and physicochemical properties of two types of sand – basalt and gravel sands, crushed stone and travertine powder have been studied. Field testing have been done on experimental road sections. Dynamic method of measuring modulus of elasticity have been applied using equipment KUAB FWD.

Travertine powder quantity, %	C2		C6		C7	
	With gravel sand	With basalt sand	With gravel sand	With basalt sand	With gravel sand	With basalt sand
0	1.44	1.20	1.15	1.06	1.24	1.07
10	1.89	2.00	1.81	2.47	2.83	1.70
15	-	-	-	3.14	-	-
20	2.63	1.84	2.28	3.94	4.29	2.40
25	3.21	-	2.57	-	-	3.71
30	3.75	1.87	2.55	3.87	4.66	4.28
35	3.42	1.60	2.30	3.29	4.18	3.94

Fig. 1. The mean values of laboratory sample’s compressive strength, MPa

3. CASE HISTORY

The technology of adding travertine powder as an additive into ready mixtures was developed after the examination of three types of mixtures (C2, C6, C7), two of which are intended for the application in base course layers, and the other one is intended for the application in the surface course layers of road pavements (Gyulzadyan H., Voskanyan G., Ter-Simonyan V. 2014). Laboratory tests have been carried out to conduct experimental research, the results of which permit to conclude that the samples of small and big aggregates, preselected by us, can be applied to prepare ready mixtures. A study was conducted of the chemical, mineral compositions of travertine powder and of the structural changes while interacting with water. Optimal quantities of adding travertine powder as an additive into the composition of ready mixtures have been identified depending on the type of sand, used in the mixtures. The optimal quantities of the additive have been identified in the result of analysis of the values of compression strength, obtained during the laboratory testing of dxh=150x150mm cylindrical samples fig. 1.

As a result there have been elaborated recommendations of introduction of travertine powder as an additive into ready mixtures of C2, C6 and C7 types with different types of sands. According to fig. 1 data in case of gravel sand for C2 mixture the optimal quantity is 25-30%, for C6 mixture – 20-25% and for C7 mixture – 20-30 %. In case of basalt sand for C2 mixture the optimal quantity is 10-20%, for C6 mixture – 20-30% and for C7 mixture – 25-30 %. The compressive strength values of samples from C2, C6 and C7 ready mixtures with gravel sand have been increased respectively about 2.42, 2.11, 3.61 times compared with the same ready mixtures without travertine powder. The same data from C2, C6 and C7 ready mixtures with basalt sand are respectively recorded about 1.6, 3.68, 3.73 times.

A study was conducted of the chemical, mineral compositions of travertine powder and of the structural changes while interacting with water. According to this study compressive strength indices of cylindrical samples were increased when travertine powder was added, because the binding mechanism was created in mixtures due to travertine powder low activity pozzolanic property.

5. RESULTS

To assess the cost-effectiveness of using travertine powder in crushed-stone-gravel-sand ready mixture as an additive, additional laboratory tests were carried out. Mixtures with optimal granulometric composition were composed, after cement CEM II 42.5N (M400) was added with percentage 1%, 2%, 3% and 4% of the mixture mass. Laboratory experiments were carried out only for a mixture C6, as it is currently the most common type of mix for RA road con-

Cement quantity, %	C6 (28 days)							
	With gravel sand			Mean values	With basalt sand			Mean values
1	0.77	0.95	0.91	0.88	1.00	0.77	0.81	0.86
2	2.08	1.40	1.62	1.70	2.20	2.40	2.09	2.23
3	3.15	2.72	2.89	2.92	3.22	3.25	3.37	3.28
4	4.30	3.70	3.82	3.94	4.21	4.11	4.09	4.14

Fig. 2. The values of laboratory sample's compressive strength, MPa

struction practice. The results obtained from above mentioned testing are presented in fig. 2 (Voskanyan G. 2014) The results were compared with data obtained from testing of samples with applying travertine powder. The comparison allows us to conclude that applying travertine powder at optimum percentages in C6 crushed stone-sand mixtures with crushed basalt and crushed gravel sand are equal to applying cement at percentage respectively 3.5% and 2.5%. Comparative effectiveness assessment revealed that for C6 ready mixtures with optimal grain size by replacing of cement binder with travertine powder the savings compose up to 21.5% in case of gravel sand, and up to 31% in case of basalt sand. Laboratory testing of samples does not allow to evaluate the influence of adding of travertine powder on values of elasticity modulus of road pavement layer with ready mixtures. For this study, we constructed an experimental road 5 m wide and 120 m long. The first section of road was constructed using crushed-stone-gravel-sandy mixture C6, and the second section was constructed using the same mixture with the treatment of optimal quantity of travertine powder. The constructed experimental road approximately 1 month was maintained under heavy traffic and different climatic impacts. After that dynamic method of rigidity field testing of the constructed road sections has carried out using KUAB FWD equipment. Testing were carried out in dry weather conditions, the air temperature +9° C. During the test were recorded registered data of deflections (f) and calculated with computer program equivalent elasticity modulus (Eeq) values. The recorded are presented in fig. 3.

The estimates values of equivalent elasticity modulus ($E_{\_EST}$) were determined using the mean experimental (E) values, measurement's coefficient of variation (CE) and the value of deviation factor (t=1.64).

$$E_{\_EST}=E\ (1-t \times C_{\_E}), \tag{1}$$

The estimates values of equivalent elasticity modulus calculated by the formula (1) are shown below:

For the subgrade $E_{\_EST}$=108 *MPa* ,

For the pavement layer with C6 mixture $E_{\_EST}$=202 *MPa* ,

For the pavement layer with C6 mixture treated with optimal quantity of travertine powder $E_{\_EST}$=248 *MPa*.

Considering the road pavement as two - layer system, known in theory of elasticity, the elasticity modulus of tested pavement layers were calculated. Calculations revealed that the modulus of elasticity's of C6 ready mixture is

Subgrade			Pavement with C6 mixture			Pavement with C6 mixture treated with optimal quantity of travertine powder		
Chainage	f, micrometer	E_{eq}, MPa	Chainage	f, micrometer	E_{eq}, MPa	Chainage	f, micrometer	E_{eq}, MPa
1+00	1582	101	0+2	902	179	0+55	442	370
1+00	1494	107	0+2	882	183	0+55	419	390
0+90	1359	119	0+10	919	176	0+65	806	200
0+90	1284	126	0+10	889	182	0+65	775	208
0+80	1512	105	0+20	471	346	0+75	412	396
0+80	1444	110	0+20	420	388	0+75	407	401
0+70	1514	103	0+30	944	171	0+85	795	203
0+70	1405	111	0+30	832	194	0+85	751	215
0+60	1465	108	0+40	614	265	0+95	813	197
0+60	1364	116	0+40	548	297	0+95	748	214
0+50	1444	112	0+50	564	289	1+05	784	205
0+50	1337	121	0+50	562	290	1+05	741	217
-	-	-	0+45	493	332	1+10	453	361
-	-	-	0+45	430	381	1+10	407	401
-	-	-	0+35	890	180	1+00	791	204
-	-	-	0+35	821	195	1+00	737	219
-	-	-	0+25	991	161	0+90	800	201
-	-	-	0+25	922	173	0+90	792	203
-	-	-	0+15	919	175	0+80	525	310
-	-	-	0+15	851	189	0+80	513	317
-	-	-	0+8	986	162	0+70	555	292
-	-	-	0+8	845	189	0+70	526	308
-	-	-	0+4	942	171	0+60	798	202
-	-	-	0+4	866	186	0+60	775	208
Mean Values								
-	1438	112	-	771	227		649	268

Fig. 3. The results of field testing

obtained value of 404 *MPa*, and the same values from the treated layer is obtained a value of 648 *MPa*. The ratio of increasing the modulus of elasticity as a result of applying travertine powder reached to 1.6 times.

6. CONCLUSIONS

The optimal quantities of applying travertine powder as an additive in crushed stone-sandy ready mixtures in case of using gravel sand are for C2 mixture - 25-30%, for C6 mixture – 20-25 % and for C7 mixture – 20-30 %. In case of basalt sand the data respectably are for C2 mixture 10-20%, for C6 mixture – 20-30% and for C7 mixture – 25-30 %. The compressive strength values of samples from C2, C6 and C7 ready mixtures with gravel sand have been increased respectively about 2.42, 2.11, 3.61 times compared with the same ready mixtures without travertine powder. The same date from C2, C6 and C7 ready mixtures with basalt sand are respectively recorded about 1.6, 3.68, 3.73 times.

Applying travertine powder at optimum percentages in C6 crushed stone-sand mixtures with crushed basalt and crushed gravel sand are equal to applying cement at percentage respectively 3.5% and 2.5%. For C6 ready mixtures with optimal grain size by replacing of cement binder with travertine powder the savings compose up to 21.5% in case of gravel sand, and up to 31% in case of basalt sand.

The modulus of elasticity's of C6 ready mixture is obtained a value of 404 *MPa*, and the same values from the treated layer is obtained a values of 648 *MPa*. The ratio of increasing the modulus of elasticity as a result of applying travertine powder reached to 1.6 times

BIBLIOGRAPHY

Sherwood Ph. (1995), *Soil Stabilization with Cement and Lime*. London: UK.

Motovilov B.P. (1984), *Increasing strength and reduced dust formation on gravel local roads*. Leningrad: RF.

Tara S., Umesh M. (2010), *Usage of Industrial Waste Products in Village Road Construction*. International Journal of Environmental Science and Development. Singapore,Vol. 1, No. 2. (p.446.)

Gyulzadyan H., Voskanyan G., Ter-Simonyan V.,(2014), *Exploration Results of Applying Limestone Powder in Crushed-stone-sand Mixtures for Road Pavement Layers. 6th International Conference on Contemporary Problems in Architecture and Contruction*, Ostrava, Czech Republic. (pp. 31-36).

Voskanyan G. (2014), *Effectiveness Evaluation of Applying Crushed-stone-sandy Mixtures Strengthened With Inorganic Binder In Local Road Pavement Layers. Bulletin of NUACA, N6(44)*. Yerevan, RA. (pp.52-59).

ANALYSIS OF THE INFLUENCE OF REACTIVE POWDERS ON THE CHOSEN HIGH-VALUE CONCRETE PRICES

POSTER

Jacek Halbiniak
Czestochowa University of Technology, Faculty of Civil Engineering, Poland
email: halbiniak@wp.pl

Keywords

concrete, reactive powders

ABSTRACT

Concrete is a composite whose properties depend on the characteristics of its components (phases), namely aggregate, concrete, additions and contact layer, which is the coarse aggregate - concrete slurry. The weakest link in the concrete is usually the point of contact of the surface of the coarse aggregate and the concrete slurry. In case of high-value concrete it is attempted to strengthen this layer by applying additions (microfiller content), which cause the reduction of porosity of this phase and improvement in aggregate grip to the concrete matrix. The result is rise in mechanical and physical concrete parameter. In this way you can get the concrete, which is very durable and has special properties. Additionally, reactive powders have a positive effect concrete contraction decrease, increase of the chemical aggression resistance and decrease of the amount of emitted warmth during the concrete hydratation. The article presents the research results concerning the influence of reactive powders on compression resistance, absorption, water penetration depth and frost resistance of high-value concrete. The compression resistance research was carried out after 28 and 56 days of the concrete hardening. There was carried out a research of the porosity characteristics of the hardened concrete for the chosen concrete series. The frost resistance research was carried out for 150 cycles of concrete freezing and defrosting. The reactive powders having been used are: siliceous dust, fly ashes, flaked ceramics and flaked pure quartz sand. All reactive powders were dosed in the amount of 10 or 15% of the concrete mass.

1. INTRODUCTION

Nowadays the produced concrete contains some additions in form of reactive powders apart from the traditional components. The reactive powders are taken to be high-value components, which modify the features of concrete mixture and hardened concrete. The use of those powders in the concrete technology is considered to be a part of the balanced development conception, which enables the reduction in the use of the natural fossil resources and the decrease of the environment pollution. The reactive powders modify the concrete structure, what leads to the improvement of the concrete properties and improvement in durability. It is important, that the used reactive powders are not produced on purpose, but that is various industrial waste having its application to the civil engineering sector, especially in the concrete technology. The dynamic industrial development leads to the increasing production of the industrial waste, which should be managed or safely stored. Meeting those requirements is considered to be a big challenge for the scientists. Waste disposal on landfills is not a good solution. It repeatedly leads to creation of enormous disposal surface, protection necessity and the analysis of their environment influence. It is a solution, which in the economic and often environmental respect arouses many reservations and protests of the local inhabitants and ecological activists. Carrying out a recycling process or industrial waste recycling seems to be a rational solution. Concrete is a material, which can be consciously modified by various additions coming from the post-production waste. In this way the applied waste to concrete may not only be managed but also it has the impact on improving the concrete component features. Nowadays there are specific products used as additions to the concrete: fly ashes (as a partial concrete substitute), microsilica, blast furnace slag and other reactive powders, what enables creating the concrete, which is more resistant to the chemical corrosion and frost. What is more, reactive powders limit the reach and porosity of the aggregate contact layer – ITZ (Interfacial Transition Zone) concrete slurry.

2. BACKGROUND

The presence of the aggregate contact layer – concrete slurry in the concrete composites was confirmed by many scientists. Until now they are not unanimous about the reasons of ITZ creation and its influence on decay process of the materials having concrete matrices. First references concerning the aggregate contact layer – concrete slurry are to be found in 1905 (Sabin L.C., 1905). However, first publications concerning the subject of the contact layer presence in concrete date back to the 1950s (Farran J., 1956). The current ITZ knowledge is presented in many publications. Despite different views, it is generally acknowledged that the aggregate contact layer – concrete slurry has higher porosity in proportion to the concrete slurry, which is remote to the grain surface of the coarse aggregate. The highest ITZ porosity level is to be found within the distance of 10-12 µm from the grain surface and it equals to 18-20% (Scrivener K.L., 1996). It means that the point of contact between the grain aggregate surface and concrete slurry is the weakest link in the concrete composite. The aggregate contact layer – concrete slurry influences not only mechanical properties of the concrete but also physical properties like cyclical freezing and defrosting resistance (Sicat E., 2014). The appropriate amount of the reactive powders reduces capillary pores and modifies profitably the ITZ microstructure, improving in this way the parameters of the hardened concrete, compression and frost resistance and absorbability. Nowadays microsilica and fly ashes are generally added to the concrete composite, though there are also used other additions, which influence positively on the concrete properties. Many scientists admitted that microsilica improves the properties of the concrete. It is well-known that an addition in form of microsilica seals the concrete matrix and the aggregate contact layer – concrete slurry, increases the durability as well as concrete resistance and reduces its absorbability. Trilok Gupta and other scientists proved that microsilica improves also impact resistance of the concrete (Gupta T., 2015). Mahmoud Nili and the others proved in their researches that microsilica and nanosilica increase the growth pace of the concrete resistance and modify the aggregate contact layer – concrete slurry (Nili M., 2015). Similar research results were shown in (Mukharjee B.B., 2014), where the concrete hardness and grindability with an addition of silica were proved. An addition in form of microsilica and fly ashes influences positively the chloride corrosion of the concrete. Moreover, fly ashes improve the fluidity of the concrete mixture and its plasticity, thanks to which it is used to the self-compacting concrete (Wongkeo W., 2014). Fly ashes are applicable to the concrete both as a concrete substitute but also as microaggregate. The basic fly influence is connected with the properties of concrete mixture and concerns water demand and plasticity. It influences profitably the plasticity of the concrete mixture, it has plastifying properties, causes the improvement of the solidity and prevents its segregation. Fly ashes have, indeed, a huge influence on the improvement of the mixture concrete tightness and corrosive concrete resistance. In the age of the increased production of industrial waste, some people try to apply various waste material to the concrete, which are treated as microfillers or aggregate. In the work (Rajczyk J., 2014) there were applied granulated waste from grit chamber from the water treatment plant as a partial sand substitute. More often, those are household and sanitary ceramics, which are applied to the concrete composites. Medina and the others (Medina C., 2012). applied household and sanitary ceramics to the concrete as an aggregate substitute. The concrete with the addition of the sanitary ceramics proved to be more resistant to compression and tensile strength that the concrete on the basis of graveled aggregate and they were characterized by lower amount of macropores. It was proved that the ceramics aggregate contact layer – concrete slurry is more compact not as porous as graveled aggregate contact layer – concrete slurry. Ceramics aggregate from recycling was used to the concrete also by Halicka and the others (Halicka A., 2013). They proved in the researched the increased compression resistance and abrasion resistance with an addition of ceramics aggregate in proportion to the concrete with an addition of natural aggregate. They proved that the ceramics aggregate from recycling can be applied to the special concrete, working in high temperatures.

3. METHODS

The aim of the research programme was to determine the influence of the reactive powders on the properties of the concrete mixture: the content of air, consistency and concrete properties: compression resistance after 28 and 56 days, absorbability, the water penetration depth and frost resistance for 150 cycles of freezing and defrosting. There was carried out a research of porosity characteristics of the hardened concrete in accordance with the PN-EN 480-11 norm. This research consisted in pore observation on properly prepared concrete microsections and determining parameters describing the amount, size and distribution of pores i.e. - pore distribution coefficient and A300 – the micropore kontent with the greatest diameter not exceeding 300 µm. it is generally acknowledged that to create a concrete, which would be resistant to frost, the proper air bubbles distance in the hardened concrete should correspond to ≤0,20mm coefficient and the pore content with the diameter not exceeding 300µm (class 18): A300>1,5% Wawrzeńczak J., 2011). The frost resistance research was carried out in accordance with the PN-88/B-06250 norm. The research consisted in freezing the concrete specimens, which were saturated with water in

Components [kg/m³]	Concrete series								
	C	S10	S15	A10	A15	CE10	CE15	SA10	SA15
Concrete	332	332	332	332	332	332	332	332	332
Water	158	158	158	158	158	158	158	158	158
Aggregate	1993	1960	1943	1960	1943	1960	1943	1960	1943
Superplasticizer	6,64	8,3	8,3	6,64	6,64	6,64	6,64	6,64	6,64
Microsilica	-	33,2	49,8	-	-	-	-	-	-
Fly ash	-	-		33,2	49,8	-	-	-	-
Crumbed ceramics	-	-	-	-	-	33,2	49,8	-	-
Crumbed quarto sand	-	-	-	-	-	-	-	33,2	49,8

Fig. 1. The mean values of laboratory sample's compressive strength, MPa

Concrete properties	Concrete series								
	C	S10	S15	A10	A15	CE 10	CE 15	SA 10	SA 15
Compression resistance after 28 days f_{cm} [MPa]	54,5	68,9	77,9	59,9	62,5	55,9	57,2	62,2	65,7
Compression resistance after 56 days f_{cm} [MPa]	56,0	70,3	80,1	63,5	66,0	57,3	59,9	63,3	68,7
Water penetration depth [mm]	88	72	69	92	94	88	87	85	81
Absorbability[%]	4,8	3,5	2,9	4,8	4,7	4,7	4,7	4,0	3,9
Resistance decrease after 150 cycles of freezing and defrosting [%]	12,3	8,8	7,0	11,0	10,7	12,0	11,5	10,1	8,7
Mass loss after 150 cycles of freezing and defrosting [%]	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00
Pore distance coefficient $\bar{L}$ [mm]	0,21	-	0,18	-	0,18	-	-	-	-
Micropore content A_{300} [%]	2,2		2,5		3,2				
Air content [%]	2,1	2,4	2,45	2,9	3,3	2,3	2,3	2,1	2,0
Cone fallout [mm]	44	60	11	120	165	38	37	30	12

Fig. 2. The values of laboratory sample's compressive strength, MPa

the temperature of -20oC (4 hours) and defrosting the specimens in the temperature of +20oC (4 hours). There were carried out 150 cycles of freezing and defrosting. After those cycles the decrease in concrete resistance and mass loss were stated. The study focused on the control concrete without an addition of the reactive powders and modified concrete: microsilica, fly ashes, crumbed quartz sand and crumbed household ceramics. All of the additions were dosed in quantities: 10 and 15% of the concrete. In the modified concrete the additions did not make any changes to the concrete but there was made a correction in the amount of aggregate. The household ceramics came from the waste , which was created by the ceramic pot production, which had flaws in form of cracks, scratches and glaze damage. The pots were crumbed in the disintegrator. The applied fly ashes met the requirements of the PN-EN 450 norm. Roasting loss of the applied fly ashes: 4,2%. A Portland concrete CEM I 42,5R and liquid additions based on polycarboxylates were applied to the concrete. In the table 1 there were presented the concrete compositions of the researched concrete.

4. RESULTS

For all concrete mixtures there was carried out a air content research in accordance with the PN-EN 12350-7 norm and consistency research of the cone fallout in accordance with the PN-EN12350-2 norm. The compression resistance research was carried out in accordance with the PN-EN 12390-3 norm, water penetration depth research in accordance with the PN-EN 12390-8 norm and absorbability and frost resistance research for 150 cycles in accordance with the PN-88/B-06250 norm. The results of the concrete research were presented in the table 2. For three concrete series: control concrete (C), with the addition of microsilica in the amount of 15% (S15) and with the addition of fly ashes in the amount of 15% (A15) there was carried out a research of porosity characteristics in accordance with the research procedure stated in the PN-EN480-11 norm. The research was carried out with the help of an automatic system, which analyses air pore images in the concrete and computer programme Lucia Concrete. The research results were presented in the table 2. The applied reactive powders influenced highly mechanical and physical properties of the concrete. The concrete with an addition of microfillers reached higher average values of the compression resistance than in comparison with the control concrete after 28 and 56 days. The greatest compression resistance growth was noticed by the concrete with the addition of microsilica (series S10 and S15). The average compression resistance of this concrete was higher by 26% (series S10) after 28 days and 43% (series S15) in comparison to the compression resistance of the control concrete. Analogous this growth 56 days reached the values: for S10 series – 25,5% and for S15 series – 43%. All applied additions caused the reduction in water penetration depth in comparison to the value reached by the control concrete. The concrete with the addition of fly ashes (series A10 and A15) and crumbed household ceramics (series CE10 and CE15) reached similar absorbability values in comparison to the absorbability of the control concrete. Whereas, both the addition of microsilica (series S10 and S15) and crumbed quartz sand (series SA10 and SA 15) caused the reduction in the absorbability in comparison to the control concrete. All types of concrete proved the frost resistance in the range of 150 cycles. In accordance with the PN-88/B-06250 norm the concrete, for which the strength decrease after 150 cycles is lower than 20%, and the mass loss is smaller than 5%, is considered to be a frost resistant concrete. In the research of concrete porosity characteristics the reached values of pore distance amounted from 0,21 to 0,18mm. The micropore content A300 in the control concrete amounted to 2,2% and in the concrete, which was modified with microsiliica (S15) and fly ashes (A15) respectively: 2,5% and 3,2%.

5. CONCLUSIONS

On the basis of carried out research programme and result analysis it was concluded:

- Reactive powders in form of microsilica, fly ash, crumbed household ceramics and crumbed quartz sand are very useful concrete additions. They modify the structure of the hardened concrete, seal the concrete matrix and the aggregate contact layer – concrete slurry. Moreover, they make better all of the concrete properties, which are: compression and frost resistance, absorbability and water penetration depth.

- Despite the lack of the addition improving frost resistance, the concrete with the addition of the reactive powders was found to have better frost resistance than the control concrete. The greatest pore content in class 18, namely in 285-300μm size, was found by the concrete with the addition of fly ashes (A15). The remaining two types of concrete, for which there was carried out a porosity research i.e. control concrete (C) and concrete with the addition of 15% of microsilica (S15) reached smaller values of micropore content. Nonetheless, all of the researched types of concrete reached the micropore value, which was more than 1,5% and thereby it guaranteed a high frost resistance. All researched types of concrete reached the value of pore distance, which was smaller than 0,2mm, what guarantees a good frost resistance as well.
- Fly ashes applied as an additional concrete component improved both the properties of the hardened concrete and influenced positively the plasticity of the concrete mixture. Concrete mixtures with the addition of fly ashes had greater consistency classes: S3 (for A10 series) and S4 (for A15 series) in comparison to S1 consistency class of the control concrete mixture. Fly ashes can be successfully applied to self-compacting mixtures and to mixtures used by the pumps.
- A very good example of managing of the production waste is also crumbed household ceramics coming from the damaged ceramic pots. The addition of the crumbed household ceramics improved the concrete compression resistance in comparison to the control concrete. After 56 days the concrete with the addition of the crumbed household ceramics had higher compression resistance: by 2,3% (CE10 series) and by 7% (CE15 series) in comparison to the control concrete. The addition of the crumbed household ceramics improved insignificantly the concrete frost resistance, and the absorbability and the water penetration depth reached the same level as the one by the control concrete.
- Crumbed quartz sand turned out to be a very good reactive powder. The concrete with the addition of crumbed quartz sand was found to have a better concrete strength after 28 days: by 14% (SA10 series) and by 20,6% (SA15 series) in comparison to the average strength of the control concrete. Similar conclusions were made for the concrete, which was researched after 56 days. The SA10 series concrete reached a greater concrete strength by 13% and SA15 series concrete by 22,7% in comparison to the average compression resistance of the 56-day-control concrete. The concrete with the addition of crumbed quartz sand had smaller values of the absorbability and the water penetration depth than the control concrete.
- Concrete with the addition of microsilica had the best properties among all of the researched types of the concrete. This addition is suitable for the production of the high-value concrete, which have small absorbability and small water penetration depth. On account of the size of the microsilica grains, concrete having this addition are characterized with higher water demand, what results in the necessity of applying greater amounts of liquid additions.

BIBLIOGRAPHY

Sabin L.C. (1905). *Cement and Concrete*. Arch. Constable and Co., Ltd, London, 1905

Farran J. (1956). *Contribution mineralogique l`etude de l`adherence entre les constituants hydrates des ciments et les materiaux enrobes*. Rev. Mater. Constr., Trav. Publ., No 490-491, 492,

Scrivener K.L., Kamran M.N. (1996). *The percolation of pore space in the cement paste/ aggregate interfacial zone of concrete.* Cem. Concr. Res., 26, 1.

Sicat E., Gong F., Ueda T., Dawei D. (2014). *Experimental investigation of the deformational behavior of the interfacial transition zone (ITZ) in concrete during freezing and thawing cycles.* Construction and Building Materials 65, 122-131

Gupta T., Sharma R.K., Chaudhary S. (2015). *Impact resistance of concrete containing waste rubber fiber and silica fume*, International Journal of Impact Engineering 83, 76-87

Nili M., Ehsani A. (2015). I*nvestigating the effect of the cement paste and transition zone on strength development of concrete containing nanosilica and silica fume*. Materials and Design 75, 174-183

Mukharjee B.B., Barai S.V. (2014). *Influence of incorporation of nano-silica and recycled aggregates on compressive strength and microstructure of concrete*. Construction and Building Materials 71, 570-578

Wongkeo W., Thongsanitgarn P., Ngamjarurojana A., Chaipanich A. (2014) *Compressive strength and chloride resistance of self-compacting concrete containing high level fly ash and silica fume*. Materials and Design 64, 261-269

Rajczyk J., Respondek Z. (2014). *Study of Concrete Composite with Participation of Waste from Sewage Plants.* Advanced Materials Research

Medina C, Sánchez de Rojas M.I., Frías M. (2012). *Reuse of sanitary ceramic wastes as coarse aggregate in eco-efficient concretes.* Cement & Concrete Composites 34, 48-54

Medina C., Frías M., Sánchez de Rojas M.I., Thomas C., Polanco J.A. (2012). *Gas permeability in concrete containing recycled ceramic sanitary ware aggregate*. Construction and Building Materials 37, 597-605

Halicka A., Ogrodnik P., Zegardlo B. (2013) *Using ceramic sanitary ware waste as concrete aggregate*, Construction and Building Materials 48, 295-305

Wawrzeńczak J, Molendowska A. (2011). *Struktura porów, a mrozoodporność betonów napowietrzanych za pomocą mikrosfer*. Cement Wapno Gips

APPLICATION OF GREEN CONSTRUCTION TECHNOLOGIES IN XX PROJECT

Zhiyuan He[1], Jun Dong[2]
Beijing University of Civil Engineering and Architecture, China
email: [1] 790672856@qq.com, [2] jdongcg@bucea.edu.cn

Keywords

reinforced concrete structure, building template, four conservations and one protection

ABSTRACT

Developing green buildings using the green construction technology is the fundamental key to improving our living environment, reducing energy consumption in the building industry and solving the energy issues in China. This paper attempts to analyze the application of green construction technology in XX project using the methods of engineering management and systematic analysis. This paper begins with the necessity of applying green construction technology in construction engineering projects, proceeds with the introduction of some green construction technologies, such as the reinforced concrete structure, the building template, "four conservations and one protection" and the selection of green building materials and ends with some possible solutions to problems arising from these applications.

1. INTRODUCTION

The recent progress of science and technology also promotes the development of construction technologies. New technologies, new materials, and new equipments are emerging, pushing forward the development of high-rise residential buildings and office buildings of reinforced concrete structure. Nowadays, sustainable development has become the common pursuit of mankind in the world; China has laid down a new policy of the "scientific outlook on development"; it also requires on the creation of a "resource-saving and environment friendly society". As a result, a "green revolution" is taking place in the building industry, and we hear an urgent call for the green building and the green construction. Green building is the development trend of urban construction at home and abroad, because it makes a comprehensive response to environmental issues, and represents the application of the strategy of sustainable development and the theory of circular economy in the construction industry. As the implementation means of the green building, green construction points out the direction in the future development of the construction field. Urban constructions, especially those of high-rise buildings, need to adopt the method of "green production", that is, to save energy, reduce consumption and reduce the amount of pollutants produced and emitted, in order to reduce the negative impact on environment. Developing and implementing green construction is the main embodiment of the concept of sustainable development in urban construction, and the objective requirement of realizing the sustainable development of the construction industry, establishing an energy-conserving society, and developing the circular economy.

2. BACKGROUND

XX project is located in the northeast corner of the Chao Yangmen Overpass in the East Second Ring Road of Beijing. The area covered is 21673 m2 and the total construction area is 223459 m2, with 26 floors above ground and 4 floors underground. Overall, the project is a well-equipped, 5-A grade high-rise building that covers a large area and has a strong sense of modernity.

3. METHODS: The Application of Green Construction Technologies in XX Project

3.1 Reinforced Concrete Stucture

• *3.1.1 Steel Structure*

In this project, the stressed reinforcements with a diameter of over 12mm all adopt the HRB400 grade steel. There are two reasons for this: 1) Using the HRB400 steel bar can improve the reliability of the concrete structure and is economical. Theoretically, using the HRB400 grade steel can save about 10% - 15% of steel than using the HRB335 steel. Therefore, this measure can improve the utilization of the steel and reduce the total cost. 2) In outlook, the HRB400 steel bars differ very little from the HRB335 steel. As a result, if both of them are used in the project, it would be very difficult to classify them. Even serious accidents may occur if the two kinds of steel bars are mixed together. Therefore, in this project, the stressed reinforcements with a diameter of over 12mm use only the HRB400 grade steel.

Experience tells us that the ultimate tensile strength and yield strength of the HRB400 steel are prone to problems. Therefore, we strictly selected HRB400 steel manufacturers and gave priority to factories with good quality stability, such as Shougang Group. At the same time, we strictly carried out the site acceptance and reexamination after entering the site, in order to prevent the use of unqualified products which can bring great harm to the structure safety.

We managed the reinforcement by following the method of "optimizing reinforcement and comprehensive feeding". That is to say, according to the reinforcement list optimized and made by the computer, for grade I steel bars, we conducted the cold pulling processing and stretched them by 4%. In this way, we not only removed the rust, but also saved the amount of steel bars. For the connection of steel bars, we use the rolling straight screw connection, reducing the amount of reinforcement. In this project, for the thick steel bars with a diameter ≥Φ16, we use the strip rolling straight screw sleeve connection, which is currently the most advanced and the most commonly used reinforcement mechanical connection method. This method has the characteristics of high strength, simple process, low cost and good reliability.

• *3.1.2 Concrete Structure*

In the premise of meeting concrete strength and various performance indexes, the double admixture of grade one fly ash and granulated blast furnace slag was studied. Fly ash and slag are used to replace some cement, which can dispose of a large amount of industrial waste and at the same time can reduce the consumption of cement.

We control the total content of alkali in concrete, use low alkali active sand aggregate so as to prevent the concrete from alkali aggregate reaction. We control the content of CL- in concrete, so as to reduce the corrosion degree of concrete to the steel bar and prolong the life of concrete. We also control the content of ammonia in concrete, so as to prevent harmful substances volatilizing and injuring the human body. And by controlling the radioactivity of concrete raw materials, we reached the target of reducing the radioactivity of concrete.

3.2 Building Template

In this project, all the frame columns and beam boards adopt the wood keel coated plywood formwork, the bowl buckle type scaffold, and the early removal stigma, which form the quick disassembly system. The early dismantling template system has distinct advantages and features: 1) it is one-time investment and can save nearly 2/3 template and 60% supporting materials. 2) It can shorten the construction period by speeding up the turnover of the template 2-3 times. 3) It can extend the service life of the formwork, reduce labor costs and reduce the on-site transportation costs of the formwork materials.

Coated plywood has a smooth surface, large board size and less seams, and can achieve the effect of clear water concrete construction.

The early dismantling template system boasts of high construction efficiency because it can reduce the plastering workload, improve the turnover efficiency of the templates, save template inputs and its surface can be meet the requirements of the clear water concrete.

3.3 Four Conservations and One Protection

• 3.3.1 Energy Conservation

For exterior walls and interior walls and floors that require insulation, we apply the lightweight and efficient energy-saving insulation materials and adopt the latest technology, making sure that the average heat transfer coefficient K of the building envelop is less than or equal to 0.6w/m2k, so as to meet the third-step energy-saving requirement in Beijing to 65% degree. In this project, large areas of ceilings apply the ultrafine inorganic fiber coating insulation layer. In addition, all the exterior walls and the reflection glass curtain walls in this project adopt the Low-E insulating glass with a 12mm-thick insulating layer and the PA broken bridge aluminum alloy. This is to say, this project walks at the forefront of energy-saving and environment protection by combining the three major energy-saving door and window technologies, i.e. “the bridge section”, “the insulating glass” and “the low radiation rate of glass”.

• 3.3.2 Land Conservation

Within the limit of the project plan, we increase the plot ratio as much as possible, make the top floor into slope roof or back layer and narrow the width and increase the depth as far as possible.

• 3.3.3 Water Conservation

In the construction period, we adopt the water-saving technologies and facilities. We reuse the water as many times as possible, for example, we reuse the water to wash vehicles and spray on-site roads. The amount of water used for the construction is measured and taken down. In room temperature stage, we use sprayer to conserve the concrete, instead of the water hose. At the same time, on-site taps all use water-saving faucet.

• 3.3.4 Materials Conservation

Pipes are used rationally. Long pipes are not used for short purpose. Short pipes are used for processing joints. A certain amount of steel casing is made according to the size and specifications of the reserved holes on the floor. We recycle the steel cases to reduce the amount of wood.

• 3.3.5 Environment Protection

1) Planted roof and earth covering on the roof of the basement: The project has a large-scale greening platform, i.e. the planted roof. In addition, on part of the roof of B1, subsidence earth covering is designed. The total greening area is nearly 20,000 square meters. The water proofing of the planted roof and the irrigation of the subsidence earth covering is also studied.
2) Construction Waste Disposal: We reduce the amount of waste produced in the construction period by classifying, recycling and reusing the waste. We also effectively control the flow direction of the waste and prevent disorderly dumping and secondary pollution.

3.4 Green Building Materials

• 3.4.1 Ready Mixed Mortar

In this project, all the masonry and plastering works use the ready mixed mortar, which is conductive to ensuring construction quality, energy-saving and environment protection. The roof slope layer of the project is nearly 17, 000 square meters and its leveling layer uses the 20-thick DS mortar. The 20-thick DS mortar is a new type of environment protection dry powder, which is mixed and packaged in the factory. It has excellent water-retaining property because the chemical additives prevent water evaporation and eliminate the dry shrinkage crack. It has good bonding with the concrete, so no interface agent is needed and its surface is firm and crack-free. It is non-toxic and has no odor, so it is environment friendly.
Close attention is paid to the vertical flatness of the filler walls because this can reduce a large amount of plastering and therefore save the use of mortar. When we mix mortar on site, we often use fly ash or lime to replace the concrete after we design specific mix proportion and after the design company and the supervision company have approved the proportion.

We reuse the mortar that falls on the ground. If it is fit for use, we put it immediately on the wall. If not, we sieve it and remix it according to the mix proportion. In this way, we save the use of cement and sand.

• *3.4.2 Vapor Pressure Aerated Concrete Block*

The inside and outside filler wall in the project is vapor pressure aerated concrete block wall. Steam pressure aerated concrete block is a new type of porous lightweight wall material, with good fireproofing, heat insulation, and sound insulation; and the product has smooth surface and precise size, with high thermal resistance and light weight, which saves a great deal of masonry mortar and therefore improve the construction quality and speed.

4. RESULTS

Through the application of green construction technology, XX project has achieved good economic benefits. Thanks to the four conservations, the project saves about 500,000 Yuan. Studies have shown that only through the rational use of resources, through the overall control of the construction, through the reform of the construction technologies, through the minimization of the wastes and pollutants produced and emitted, and through the coordination of on-site construction with environment, can we truly achieve the green construction and the sustainable development.

5. CONCLUSIONS

Based on the construction facts, we ascertain the following improvement directions: formulate scientific construction schedule, use environmentally friendly engineering machinery, improve the reuse of engineering machinery and parts, and attach importance to the recycling of construction waste.

BIBLIOGRAPHY

He, Xiaofei. (2011). *The Study on Cost Analysis and Control in Green Construction of High Rise Building,* Xi' An: .Private Science and Technology.

Yang, Yongning. (2007). *Report on Application of Green Construcion Technology to Omron Engineering Project. Shanghai: Building Construction.*