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Early-Age-Crack Control: A Case Story

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Summary

Increased demands to achieve durable concrete structures with increasingly longer service life requires more detailed investigations and knowledge of e.g. potential chloride ingress or risk of cracking in the concrete due to heat generation during hardening and/or shrinkage. In the last 10-20 years concrete mixes have moved towards more dense concrete to obtain high resistance to chloride ingress. As the concrete becomes more dense the concrete mechanical properties change and often the risk of cracking increases, which consequently can reduce the durability of the structure. In other words durable concrete can under improper use cause non-durable structures.

By means of computer simulations of the hydration temperature and the temperature induced stresses it is possible to predict the risk of cracking and to determine appropriate measures to reduce the risk of cracking. It is possible during planning of massive concrete castings to minimise the preventive measures required to reduce the risk of early age cracking such as cooling.

This paper will be based on three case stories from the Great Belt Link and The Oresund Link projects in Denmark, which demonstrates that the potential crack risk can be simulated quite accurately. Based on three dimensional simulations the importance of the static boundary conditions are discussed and it will be demonstrated that under certain circumstances it is impossible to avoid early age cracking due to the effect of autogeneous shrinkage.

Conclusions

Based upon the presented case stories we find that the following statements can be raised.

1. 3D dimensional analyses will be required in the future. A lot of assumptions regarding static boundary conditions can calculated instead of being assumed.

2. Single cooling pipes does not have to be modelled in relation to evaluation of global effects. This approach is equivalent to concrete design where the single reinforcement bar is often not modelled.

3. Prediction of potential crack risk can be calculated very accurate if all information is known. It is very important before any calculations are started or required as documentation, that acceptance criteria and input parameters are agreed.

4. To avoid the problems mentioned in 3 a guide or code of practice in relation to computer simulations of early age crack risk is needed.

5. By performing preliminary evaluations of the crack risk, cost can be reduced e.g. by avoiding expansion joints in some structures.

Rock-Concrete Structures

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Stanislaw Dominas, born 1931, received his civil engineering and MSc. degree from the University of Wroclaw in 1957 and Doctor degree in 1975. He has designed and realised many buildings during his professional work. In 1966, he had started didactic and research works in the University. Presently, he manages an own research enterprise of building structures.

Abstract

Compression strength of special concretes for high loads will yet not reach a higher value that R_C=40-60Mpa in engineering practice. Further efforts to increase this strength will be determined with an unproportionated way by the cement binder even at its proper modification as a concrete composite matrix.

In a concrete composite, this cement matrix is the main cause of an unfavorable concrete creep and it is impossible to reach a better use of its load-carrying component i.e. rock aggregate.

In the same time, compression strength of basic rocks used in building technology such as basalt, porphyry and even granite is in fact quite sufficient for future structural needs.

Strength of these materials is equal to R_C=200-400Mpa and in structures made from traditional concretes is used in 10 - 20% only. Therefore there are carried out actions to apply solid rocks into compressed area of concrete beam cross-section instead of concrete. Such solution will multiply the beam load - carrying ability. It concerns cross-sections of concrete columns, archs and especially beams submitted to beanding.

In the paper, principles of creation of rock-concrete structures and promising results of tests carried out on columns and beams are shown. The subjected solution is worthy to be considered by a wider group of investigators and creative designers operating in the building branch because rock-concrete structures may be very useful in cases wherein high loads have to be carried out therefore in objects of the future.

Innovative Deck Slabs for Highway and Forestry Bridges

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Abstract

The paper presents the developmental background for the concrete deck slab of girder bridges, in which the arching action is harnessed to such an extent that the need for tensile reinforcement is eliminated. This deck slab, which is known as the steel-free slab, is confined in the transverse direction by tying the top flanges of the girders by means of ties or straps. Five steel-free deck slabs have already been built in Canada, and have been carrying normal vehicular traffic.

The steel-free bridge deck slab, which utilises its natural arching action, has been under development for a number of years in Canada. The concept is based on a hypothesis according to which the deck slab on girders at failure behaves as an arch or a dome rather than a plate. The hypothesis has been validated by extensive experimental investigation, which has confirmed that the strength of a deck slab is enhanced considerably if it is laterally confined by ties connecting the top flanges of the girders. For the longitudinal confinement, the deck slab relies on its composite action with the girders. The deck slabs without internal reinforcement, which have come to be known as "steel-free slabs," have been tested extensively for their strength under static loads. The fatigue resistance of steel-free deck slabs under rolling wheels has been found by full-scale tests in Canada and Japan to be higher than those of the reinforced concrete deck slabs.

The arching action has already been utilized partially in the deck slabs, which are designed by the empirical method of the Ontario Highway Bridge Design Code (OHBDC). Hundreds of these slabs, which contain about 40% less reinforcement than the conventional reinforced concrete deck slabs, have been constructed during the past two decades in different parts of the world.

Design provisions for steel-free deck slabs are specified in the Canadian Highway Bridge Design Code (CHBDC); this code requires that a steel-free deck slab have a minimum thickness of the greater of 175 mm and one-fifteenth of the girder spacing. Each strap connecting the top flanges of the girders is required to have a minimum cross-sectional area, which is a function of the spacing of the girders, the spacing of the straps, the thickness of the deck slab and the modulus of elasticity of the material of the straps. The cross-sectional area of the straps in inversely proportional to the last two factors, thus confirming that this area relates to the stiffness, rather than the strength, of the straps. To control the cracking of concrete that occurs in its early life, randomly-distributed low-modulus fibres are mixed with concrete. The CHBDC specifies the minimum requirement for these fibres. It is noted that the addition of low-modulus fibres does not increase the tensile strength of concrete.

Till date, five bridges incorporating the steel-free deck slab have been constructed in Canada; four of these bridges are on regular highways, and the fifth is on a forestry road. The deck slab of the first bridge has no cantilever overhangs; horizontal vehicle collision loads on the barrier walls are designed to be carried directly to the girders and cross-frames, as a result of which the deck slab has no tensile reinforcement at all. The deck slabs of the second, third and fourth bridges have overhangs of substantial width, thereby requiring transverse tensile reinforcement near the top of the slab. In the second bridge, the carbon fibre reinforced polymer rods are used as the tensile reinforcement for transverse negative moments, and in the fourth glass fibre reinforced polymer is used for this purpose. The deck slab of the fifth bridge, being a forestry bridge, is of precast construction.

The distress-free performance of the steel-free deck slabs of five bridges in Canada from the Atlantic coast to the Pacific coast under unrestricted traffic has given solid support to the validity of the

concept of arching in deck slabs. A summary of the unique features of various steel-free deck slabs is presented in the following table; this table also provides information about the cost of the steel-free deck slabs with respect to that of the conventional reinforced concrete slabs.

Constn. date	Girders	Slab thickness	Unique features of deck slab
Salmon River/ Dec,1995	Steel plate @ 2.7 m	200 mm	• first steel-free deck slab in new construction. • 6 % more expensive than conventional slab
Chatham/ July,1996	Steel plate @ 2.1 m	175 mm	• first barrier wall with double-headed tension bars and GFRP grid • significantly more expensive than conventional slab
Crowchild Trail/ Sept,1997	Steel plate @ 2.0 m	185 mm	• selected on competitive bidding against conventional slab
Waterloo Creek/ Mar,1998	Precast concrete @ 2.8 m	190 mm	• first steel-free deck slab on precast concrete girders • transverse confinement by studded straps • nearly the same cost as conventional slab
Lindquist Dec,1997	Steel plate @ 3.5 m	150 mm at crown	• first steel-free precast deck slab panel • record girder spacing to minimum thickness ratio, being 23.3 • 30 % cheaper than conventional deck slab panel

It has been shown in the paper that a proper harnessing of the arching action in a concrete deck slab supported by girders can lead to deck which is entirely devoid of tensile reinforcement. The elimination of steel from the deck slab has the effect of enhancing its durability and reducing its thickness, it being recalled that the thickness of a deck slab is usually governed by the depth of cover over its reinforcement.

The economical OHBDC empirical method of deck slab design is being used in Canada and some parts of the world for more than twenty years. It is still not a recognized method of design in most of the world. The authors wonder when the steel-free deck slab will be recognized by the engineering community at large outside Canada.

Study on a Frame System with Composite Slim Floors

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Mikko Malaska, born 1967, received his civil engineering degree from the Helsinki University of Technology (HUT) in 1996. At present he is researcher at HUT and prepares his doctoral thesis on the behaviour of composite slim floor frames.

Abstract

Building frame systems based on the slim floor construction have recently gained increasing success especially in the Northern and Western Europe. Slim floor construction is competetive with conventional construction based upon reinforced concrete and composite beam solutions when savings in fire protection, cladding costs and ease integration of services are taken into account. An extensive research project has been conducted in the Laboratory of Steel Structures at Helsinki University of Technology to investigate and improve the existing methods in the slim floor design and construction. By combining the results of the structural detailing and the frame overall assembly studies, this research will establish a basis for developing a structurally competetive and cost-effective steel-concrete composite slim floor frame system and ensures an optimized quality for both the design and construction of the frame system.

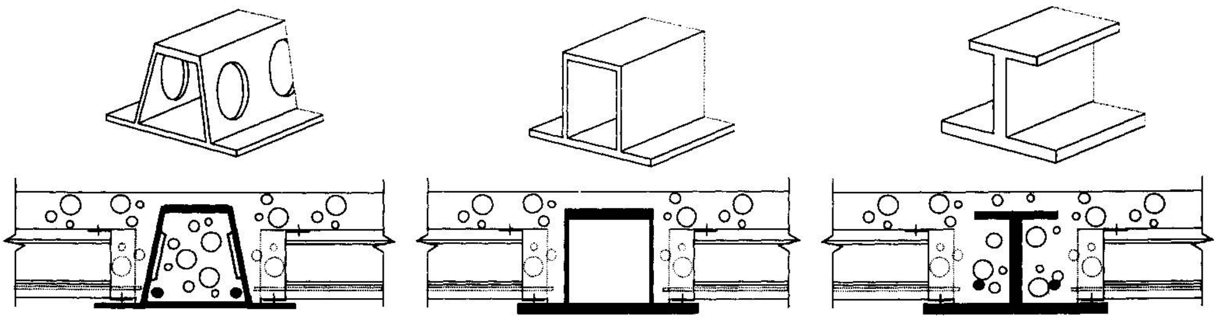
Nowadays, greater flexibility and open-planning in building layout are required and there is a strong demand for longer column-free floor spans. Due to the small structural depth of a slim floor, special attention should be paid in the design to increase the overall flexural stiffness of the floor. Traditional simplified floor design approaches, based on pinned or rigid connections, can not lead to the most economical solutions. Especially in the slim floor construction, it is important to connect the floor rigid or semi-rigid to the columns in order to get higher stiffness and strength, and higher lowest natural frequency for the floor. The partial continuity provided by multi-span continuous structures and semi-rigid beam-to-column connections is an important factor affecting the floor performance and allowing significant reductions in the floor depth, permitting shallower and lighter beams and reducing the overall cost of the floor system. Lot of research has been done and many national standards and design recommendations have been published recently on the slim floor design and construction. To establish a basis for the design and further development of the slim floor construction, this research project at Helsinki University of Technology is started.

In the slim floor construction, the beams are contained within the depth of the concrete of the slab and the concrete is cast to fill the voids around the steel beams in order to increase the fire resistance, the sound insulation and the strength and the stiffness of the beams. In this research, the capacities of the most common slim floor beam sections are analysed and compared. Calculations are carried out for single-span, two-span continuous and single-span precambered beams in order to find out the maximum floor spans and the critical design conditions for the slim floor beam.

In practice, the reinforcement in a concrete slab contributes to the resistance and the stiffness of the beam-to-column connection and the majority of the connections may be considered as semi-

rigid with a partial resistance. The modelling of connections as semi-rigid is more realistic and it utilizes the semi-continuity between the members of a frame offering a potential for significant benefits. Satisfactory prediction models are currently proposed covering the most popular connection forms in conventional composite frames and manuals including tabulated connection capacities for standard connections are prepared for designers. For slim floor systems, the application rules available are very few in number and further research is required in order to realise the benefits of the semi-continuity also in the design of composite slim floor frames. Ongoing extensive research project at Helsinki University of Technology focuses on the behaviour of the semi-rigid connections in a frame system consisting of slim floor elements. At present, the beam to I-shape steel column connections are widely studied internationally. A new technology is necessary to connect the slim floors to the tubular composite columns and the methods approximating the moment-rotation (M-ϕ) curve of the connection for this type of connection should be created. The experimental part of the research project, including full-scale beam-to-column connection tests for a slim floor subframe will be carried out by spring 1999.

The main objective of this study was to analyse both experimentally and theoretically the behaviour of the low-rise composite slim floor frames and to develop a structurally efficient frame system with a high construction quality. The influence of the new stricter requirements for the fire and sound insulations in the building frame is studied and applied for the slim floor structures. To achieve long column-free floor spans, the continuity of the beam connections is to be taken into account in the frame design. Final results of this research project for developing a new slim floor frame system will be collected and analysed after the extensive full-scale testing on the frame system.



a) Delta-beam b) HQ- or Closed top-hat beam c) Asymmetric I-beam

Fig. 1 Slim floor beam sections.

Keywords: Composite construction; steel-concrete; slim floor; frame; semi-rigid connection

Integrating Automation into the Life Cycles of Structures

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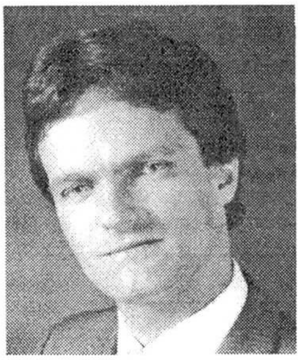


David Cobb, born 1957, chartered civil engineer, received his civil engineering degree from Surrey University and has since obtained Masters degrees in geotechnics and business administration. He is actively involved in EU research projects and helping organisations to win funding from Europe.

Summary

High-rise, long-spanning or simply repetitive-shaped structures lend themselves to automation and "robotisation". Automation concepts may be incorporated in many stages of their life cycle. This paper reports on a world-wide market research exercise which sought to establish respondents' views and knowledge in this area. Drivers for introducing such concepts include, in order of rank: productivity; quality; safety; working conditions; labour cost savings and standardisation. Quality of construction can be enhanced by removing/reducing human error, which frequently arises from on-site fatigue, itself a legacy of the construction environment. Savings of nearly 15% , achievable in only 5 years, for a typical building with the introduction of automation concepts are described. Cross-fertilisation and awareness programmes are needed to educate students and practising construction professionals alike.

Keywords: automation; robotics; life cycles; buildings; maintenance; sensors; manipulators; market research; standardisation; productivity

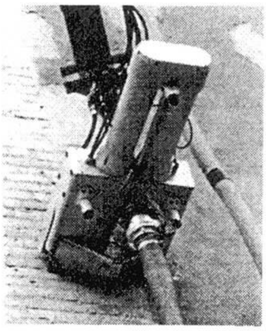
Abstract

The future competitiveness and success of the construction industry will be largely dependent upon the application of research findings, the introduction of innovative processes and products and their practical demonstration and marketing. The proposition to be tested in the underlying report to this paper (the ROBOBUILD report) was that the compound effect of introducing automation and robotics into a structure's life cycle could reduce costs without compromising on quality and safety. This proposition was tested using a detailed market research questionnaire (MRQ) with respondents coming from a world-wide geographic base.

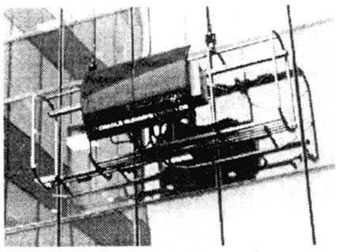
The fragmented nature of the construction industry offers both opportunities and barriers to the introduction of automation and robotics but its development should not be in isolation from other construction I.T. infrastructure developments. Robotic technology relies on series of 'toolboxes' which themselves comprise: mobility and navigation; manipulators; end-effectors; material feeding and sensing and control systems.

An MRQ question put to respondents asked them to score the level of importance when considering introducing AR into buildings and structures. The results indicated that productivity improvements ranked slightly ahead of improvements in quality and reliability. However there was strong support for improving: safety; working conditions; labour cost savings; standardisation of components; overall whole-life cost savings and simplification of operations.

There are estimated to be around 4,500 residential high-rise blocks in excess of 12 storeys height in the UK. The sums of money required are vast with, for example, London's Lewisham Authority who, in 1994/95 identified the need for an additional £40m to address problems that have a 'working at height' component alone. Thus anything that can be done to drive down the costs of assessment and remedial work by integrating automation techniques into the life cycle of structures will be welcomed by housing authorities across the UK. Systems, such as that shown right, can make light work of removal of loose or poor rendering by achieving up to 400m^2/hr productivity



System BIBER removing roughcast



OCS's ARCOW window cleaner in action

The robotisation of window cleaning is one area that has been receiving much attention in recent years and new systems, such as that shown left, may rely on mullion design being incorporated very early on in a new building concept.

Taking a look at one detailed response to an MRQ question respondents were asked to score achievable reductions in the construction of a typical office block with the application of automation and robotics. The results are tabulated below:

	Element	Typical average current costs (%)	Mean % reduction in 5 years with the application of AR	Potential average savings (%)
1.	Wall finishes	2.5	19.9	0.5
2.	Floor finishes	3.5	18.6	0.65
3.	External envelope	16.5	17.4	2.87
4.	Frame	5.5	17.1	0.94
5.	Services	34	16.3	5.54
6.	Ceiling finishes	2.5	15.7	0.39
7.	Upper floors	2.5	14.6	0.37
8.	Roof	5	12.7	0.64
9.	Prelims, fees, site costs etc.	7.5	12.0	0.90
10.	Substructure	7	12.0	0.84
11.	Internal divisions	9	11.8	1.06
	Total average saving possible in 5 years time for a complete structure with the introduction of automation and robotics into the construction process.			**14.70%**

The paper offers a number of conclusions and recommendations and to some extent these are already being implemented and will be reported upon at the conference. For example, a UK proposal to establish a network that bridges the technology-push market-pull gap has been submitted and a major EU-sponsored project has been launched that embraces these technological and economic issues. A good starting point for anyone wishing to deepen or develop their understanding of these issues is to visit the web site of the International Association for Automation and Robotics in Construction (IAARC) at http://www.iaarc.org.

New skills and ways of thinking need to be introduced into tertiary educational courses and by means of continuing professional development. Only then will professionals be able to consider how quality aspects can be enhanced by integrating automation concepts into the life cycles of structures.

The Øresund Bridge: Monitoring Construction Quality

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Örjan Larsson received his MSc degree in civil engineering from the Technical University of Lund, 1969. He worked for NCC as a Contractor until he joined Øresundskonsortiet in 1993. He is Contract Director responsible for the Øresund Bridge Contract.

Abstract

The Øresund Bridge is part of the fixed link under construction between Denmark and Sweden. Øresundskonsortiet is the Owner of the Link and responsible for its implementation, operation and maintenance. ASO Group, consisting of Ove Arup & Partners (GB), SETEC (F) and Gimsing & Madsen and ISC (DK), is the Owner's Consultant responsible for bridge concept and for monitoring the quality of the construction works. The Contractor is Sundlink Contractors HB consisting of Skanska (S), Hochtief (D) and Monberg & Thorsen and Højgaard & Schultz (DK). COWI (DK) and VBB (S) have carried out the detailed design for the Contractor. The paper describes the Owner's Quality Management Policy, first as defined in the contract documents and later as executed during the construction phase. The same principles as described here for the bridge contract have been applied to all major contracts for the Link. Opening of the Link is scheduled for July 2000.

The US$1bn construction contract for the 8km two-level road and rail bridge was awarded in November 1995. The principles behind the Owner's contract strategy were:

- 'design and build',
- 100 years service life,
- application of well-known technology and
- control and documentation of quality.

The Owner's approach to achieve his objectives is one of cooperation, which necessarily must be based on mutual confidence and trust between the Owner and the Contractor.

The Owner's requirements regarding function, aesthetics, safety and environmental protection are defined in the contract documents. Everything required to fulfil those requirements is included in the Contractor's scope of work with only specified duties on the Owner. The Contractor has been given considerable freedom regarding the means and methods. Basically the Owner specifies what the Contractor shall achieve, and the Contractor determines how to achieve it. The Contractor is responsible for supervising his own work and for providing documentation to prove that he is doing so and that as a result the work he is doing is of the quality required by the Contract. This means that the Contractor shall approve his own work. However, the Owner is monitoring the Contractor's performance.

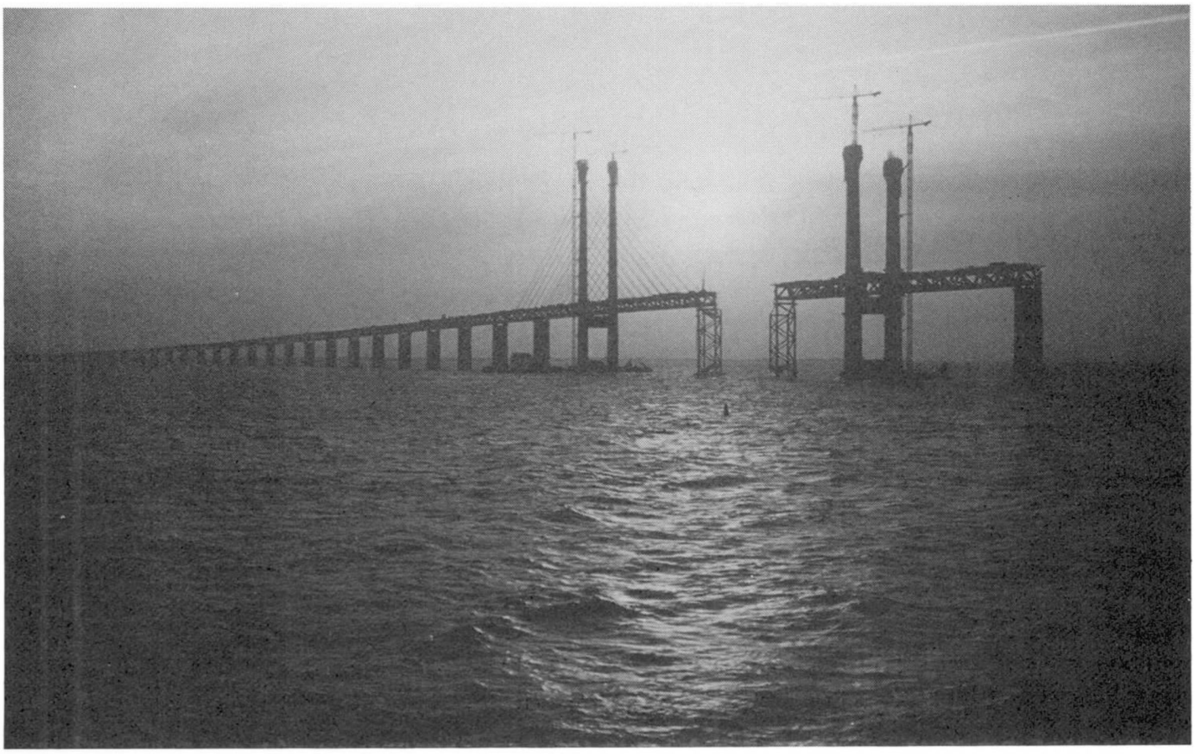
The Contractor shall establish maintain and adhere to a Project Quality Programme specifically adapted to the Contract. The PQP shall be based on the contract document, Quality System

Requirements, which in turn is based on the EN ISO 9001 standard, 1st edition. The PQP shall be documented by a Quality Manual and a number of Quality Plans (QP), which are subject to approval by the Owner.

The Contractor is responsible for the detailed design, however, his so-called basic design is subject to approval by the Owner and shall follow the contract document, Definition Drawings, which defines the visible geometry of the bridge.

The Owner's monitoring consists among others of review and approval of the Contractor's documentation, quality system audits, construction monitoring, review and approval of remedial action on non-conforming work and checking and signing off of Payment Validation Reports.

Most procedures covering the Owner's monitoring were produced before the construction contract was awarded. However, a number of the procedures concerning site queries and non-conforming work have been revised in line with the Owner's increasing confidence in the Contractor.



The 490m main span is nearing completion

There can be many reasons for developing revised and apparently relaxed procedures for the processing of site queries and of works not conforming to the Owner's requirements. One of course being the Owner's limited resources, in fact a total of only 12 to 15 people has been engaged in the Owner's monitoring of the construction work. However, more important reasons are:

- to demonstrate the Owner's confidence in the Contractor's self-control and
- to create a use-friendly system that keeps control.

The bridge is not yet complete but it is not too early to conclude that the Owner's strategy of cooperation, trust and openness has been a success. The Contract is almost 80% complete, is on time and on budget. The quality of the permanent works is to the owner's satisfactory. There have been no disputes so far and therefore no significant claims against the Owner, and none are expected either. This is not usual for a project of this size and complexity and can to a large degree be attributed to the spirit of partnership, which has been allowed to develop on this truly international project linking the two countries Denmark and Sweden.

The Jiangyin Yangtze River Highway Suspension Bridge

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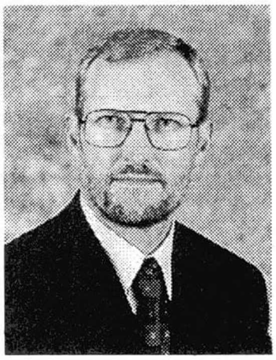
Chris Davis, born 1952, received his engineering degree from the University of Leicester. He has worked in major bridge projects throughout his career.



Summary

The Jiangyin Yangtze River Highway Bridge in Jiangsu Province, China is a 1 385 m main span suspension bridge now under construction some 200 km west of Shanghai and due to open to traffic in September 1999. Forming the most easterly fixed link across the Yangtze River, this strategic crossing will complete a new coastal road from Heilongjiang in the North to Hainan Province in the South. This paper describes the search for quality in procuring the bridge and planning its maintenance and operation.

Keywords: Suspension bridge; quality management; design; construction; operation; maintenance.

Abstract

The River Yangtze, one of the world's great rivers, is the dividing line between the North and the South of China. Construction of fixed links across it to replace existing ferry services is a key requirement in China's drive to improve internal traffic communications to assist the development of its rapidly growing economy. Since 1968 the most easterly fixed crossing of the River Yangtze has been at Nanjing, some 400 km West of Shanghai.

Jiangyin, a small town about midway between Nanjing and Shanghai, lies on a strategic route for traffic between the North and South of China. Ferries currently serve traffic on this route, and delays can be prolonged. River traffic on the Yangtze at Jiangyin is intense with the passage of vessels regularly exceeding 100 during a one hour period.

In 1991, the Jiangsu Province Communications Department (JPCD) was entrusted with the task of designing and bringing into operation a new crossing of the River Yangtze at Jiangyin. Feasibility studies established that the most effective solution was to provide a 1 385 m main span suspension bridge for the main crossing. This will be China's longest span by a considerable margin, and the fourth longest in the world.

From the outset, JPCD was determined that the procurement of the new bridge would achieve the highest possible standards consistent with internationally recognised best practice. To help achieve this objective, JPCD enlisted the support of Mott MacDonald to advise during the feasibility study, preliminary design and subsequent stages of the project.

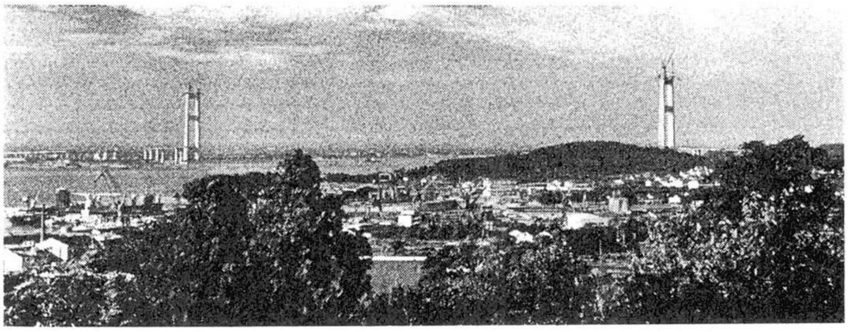


Figure 1 – Jiangyin Yangtze Bridge during construction

Building on established international practice, the design team developed the suspension bridge concept and completed detailed designs for the project. Thorough seismic and wind engineering studies, including model tests, were undertaken at Shanghai's Tongji University to confirm satisfactory performance of the structure. Large scale site trials proved the design of the very long concrete piles used for one of the main tower piers.

Major Chinese contractors built the bridge substructure, which incorporates in the North Anchorage one of the world's largest open caisson foundations. The superstructure contract was awarded to a British contractor after international tendering — the first time this procurement route had been adopted for any bridge project in China. These arrangements have demanded careful management of the construction interfaces.

Pragmatic procedures have been established to ensure that the designers' original intentions are achieved through all stages of construction. Particular attention is given to the quality of materials and workmanship to achieve a durable and robust structure. The superstructure contractor has procured fabricated steelwork, cable wire and steel castings in both China and Britain, adapting its purchase specifications, production techniques and quality assurance procedures to meet the needs of Chinese practice.

Extensive peer review during design and construction, both within the teams and by invited international experts, has made a valuable contribution to developing a world class project — and an outstanding example of close co-operation between Chinese and Western bridge engineers working together in China.

At the time of writing, construction of the bridge is progressing rapidly towards completion, in time for the bridge to be opened to traffic by China's President Jiang Zemin in September 1999. In a remarkably short time, China has planned, designed and constructed a truly world class long span suspension bridge, which is likely to be the precursor to many more similar bridge projects in China.

Bridge Construction of Malaysia-Singapore Second Crossing

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Yasumitsu WATANABE
General Manager
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Yasumitsu Watanabe, born 1948, received his civil engineering degree from Waseda Univ. engaged in many bridge Project both in design and construction.

Hiroshi OHNO
Manager
Shimizu Corporation
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Hiroshi Ohno, born 1960 received his civil engineering master degree from Univ. of Tokyo.

Summary

Malaysia and Singapore are connected with the only one causeway across the Johor Straight. Therefore it causes a heavy traffic congestion at rush hours every day. Malaysia-Singapore Second Crossing (MSSC) bridge is planned and constructed to stimulate for economic activities of western Malaysia as well as improve traffic conditions at the causeway.
The 1919m long bridge which links Landang in Johor and Tuas in Singapore across the Johor Straight (including 1769m long within Malaysian Territory) was completed on September of 1997 in only 36 months. And in order to complete this bridge in this short term construction period, the pre-cast segment construction method was adopted for approach span of 1,377m long, though remaining 357m long main span was constructed by the method of cast in-situ. This report describes a construction of the bridge in Malaysian territory.

Keywords: pre-cast segment; cantilever, cast in-situ

1. Outline of the Project

Malaysia and Singapore are separated by the Johor straight, where there has been the only one connecting road called "causeway".Traffic between two countries has become so heavy that the causeway caused a chronic jam. In order to avoid it and to accelerate the development of west district of Singapore and southern new town in Malaysia, the Malaysia-Singapore Second Crossing (MSSC) was planned and built 20km apart from the causeway.It will be able to have the capacity of 200,000 cars per day which is about double capacity of existing causeway.

MSSC Bridge is a 1919m long and six lanes (three lanes of 13.5m wide x 2) prestressed concrete box-girder which consists of four continuos bridges which formulate approach span, and one rigid frame which is for main navigation. Each approach bridge is six spans pre-cast concrete girder of 62m to 70m length. Main span consists of 96m, 165m and 96m, which is cast in-situ. The foundation of the bridge is cast in-situ pile with casing which has the diameter of 1.5m and average length of 30m. There were many cavities in lime stone layer which were plugged by concrete. The pile cap in the sea was built by caisson which was cast in the floating dock, towed and settled on the pile foundation utilizing the tide difference.

The pre-cast segment for approach span was 3.35m long and 78 to 134 tons in weight that amount to 841 pieces. They were erected by cantilever method using an advancing girder. Post-tensioning for positive moment were given by out cable, which enables us the short erection time and less labor. The main span was erected using eight large size travelers with the capacity of 800tm which also contributed to shorten the delivery.
This paper describes mainly on Malaysian side which is 1734.4m long and was completed only 36 months.

2. Segment Production

The most distinctive feature of this project is that the appoch span of total length of 1,377m of Malaysian territory has been constructed by the pre-cast segment method in order to shorten the construction period, though the remaining 357m length of main span has been constructed by the cast in-situ balanced cantilever method with large size traveler formworks.

2.1 Production Yard

A production yard for 840 segments is located approximately 20 miles far from the construction site, and has a area of 439mX150m. It contains materials and re-bars storage yard, re-bar assembling yard, 4 casting machines, segment curing shed and segment storage area. Concrete was supplied from the adjacent concrete mixing plant. The 150 tons gantry crane and a hydraulic powered transport car were used for transporting of segments.
The short line system for the segmental production was applied. All production activities were arranged in a line of 4 casting machines.

2.2 Segment Erection

Construction of the approach viaduct started at Johor abutment and continued through Pier 18 to join up with the main span. The second phase started at the other end of the main bridge and continued over Piers 21 to 23 to the interface line. Both Singapore bound and Malaysian bound lines were constructed simultaneously. (See Fig-3, Eight-Page Paper)
The typical segment erection of 70m span is shown on Fig. 7 of the eight-page paper. The erection procedure of 62m cantilever is in a similar way as for the 70m cantilever. In this case, to built up a balanced cantilever, concrete blocks were installed between the two pier segments at top and bottom slab, then 14 Nos. of temporary cantilever tendons were installed and stressed in the top slab. After placing the cantilever segments at Pier 18, the erection truss had to cross over the completed main bridge to continue working at Piers 21 to 23. The erection truss was walking over the main bridge in the same way as it was launched from pier to pier on the approach viaducts.

3. Conclusions

The entire bridge was founded on 1.5m dia. bored piles embedded into stable lime stone layer. Many cavities in the lime stone layer were specified to be grouted with mortal cement. Because of this grouting, it has spended so much time and money.
In spite of this tight and short term construction schedule, the adoption of pre-cast segment construction method has enabled this project successfully completed within given construction period.

Investigation of Highwall Carrier Made of Wood

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1. Summary

Experimental research of bearing power and deformity of highwall carrier made of wood has been displayed in this paper. These structures are often found in wood constructions but their bearing power is mostly not used. This understanding motivated research of surface highwall carriers at the Faculty of Civil engineering, University of JJ Strossmayer in Osijek. Experimental and theoretical researches were done within the scientific project "Investigation of surface highwall carrier". The research of relation H/L=1/2 carrier was accepted as a starting point at which highwall carrier effect begins at isotropic material.

2. Introduction

Wood is not homogenous material. It is mechanically anisotropic-orthotropic. These characteristics, are making difficulties in mathematical description of respond material and construction on outside forces. Mathematical modelling of surface problems in wood constructions requires hard work and powerful computer support. Theoretical results of researching don't make sense without experimental confirmation. Modern powerful computers, by using final elements program, make possible access to problem of surface wood constructions.

Highwall carriers in wood constructions are made in two levels. One is made of grillage member elements, on which lining is made of panels based on wood. Connection of those two systems is made by nailing or gluing, what is technologically possible only in a factory.

Highwall carrier constructions are mostly visible in forming vertical boulders at high building constructions, at floor and roof constructions. We find lining made of wood panels, as primary construction for overtaking outside forces, perpendicular on its planar structure. Cognition of stiffness of highwall carriers in plane can make using for overtaking of actions on its planar surface possible. Most of actions come from mail carrier's stabilisation, wind force, earthquakes etc.

There is a practical question: can the stiffness of highwall carriers be used for overtaking of actions, which are mentioned, while bracing for room's stability could be left out? Positive answer to this question is making building more economical.

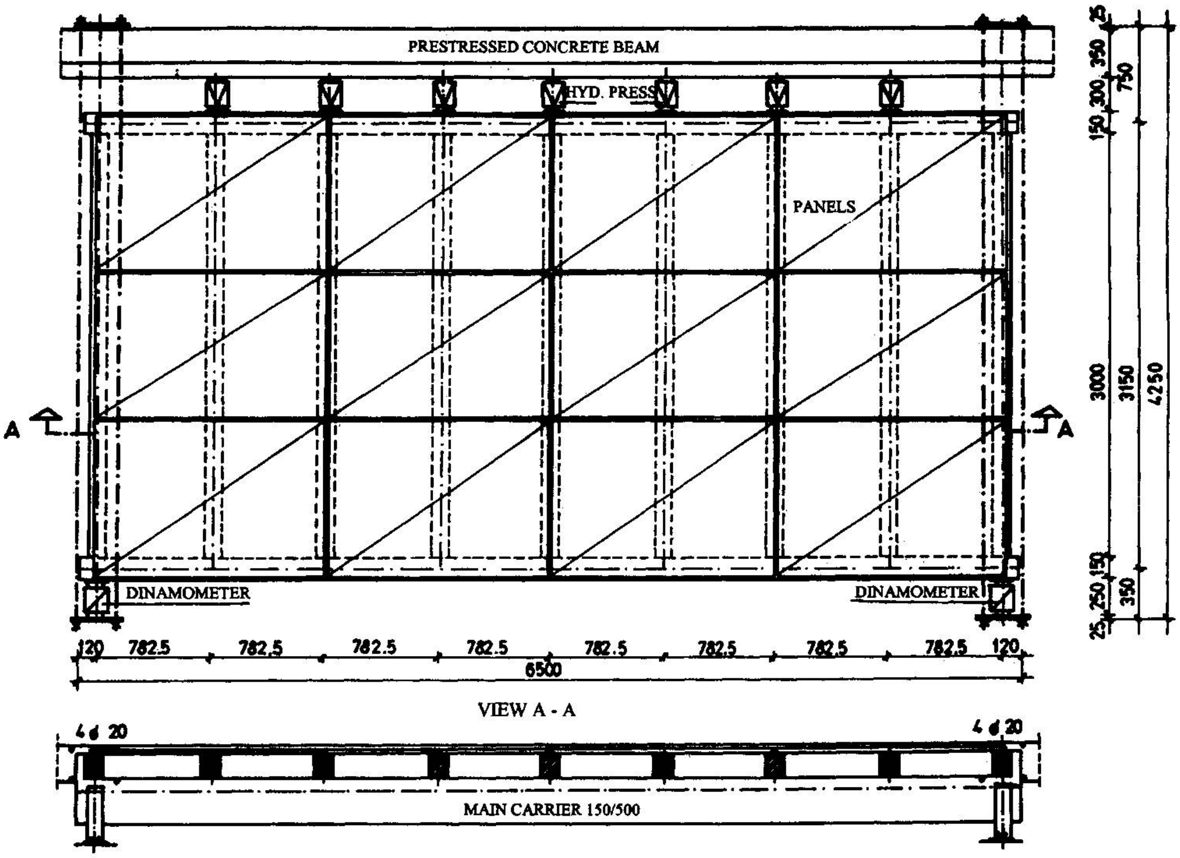

Fig. 2 Model of highwall carrier

3. The Process of Model Testing

The experimental research is done on four models:

- model I : the main grillage wooden beam (*Fig. 3*)
- model II : truss carrier formed on model II (*Fig. 3*)
- model IIIA: surface carrier, panels obesity 20 cm, nails on interval 20 cm
- model IIIB: surface carrier, panels obesity 28 cm, nails on interval 10 cm

Loading of the model was made by the system of hydraulic press, placed on connection with secondary beams.
Intensity of loading is directed to the value of mid-span displacement and is defined in norms HRN.U.C9.220 and also in DIN 1052 part 1.

Construction of the New Tenkenji Bridge

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Summary

The New Tenkenji Bridge is a cable stayed bridge with segmental method.
The construction site of this new one is located in the northern area of Kyushyu Island in Japan and across Chikugo River. In adjacent to the construction site, previous Tenkenji Bridge located and has been used for around 40 years. Now a day this bridge is too narrow to pass comfortably through and traffic load are limited to under the 4 tons vehicles only.
The New Tenkenji Bridge is planned to construct in order to improve such traffic conditions.

Keywords: cable stayed bridge; segmental method.

1. Outline of the Project

The construction site of this new Tenkenji Bridge is located in the northern area of Kyushyu Island and across Chikugo River.
In adjacent to this new bridge, previous old bridge has located and been opened to traffic around 40 years. Consequently, it has become too narrow to pass comfortably through and also traffic load are limited to under the 4 tons vehicles only.
The New Tenkenji Bridge is planned and to be constructed to improve such traffic conditions.

The super structure of the New Tenkenji Bridge is 3 spans continuous prestressed concrete cable stayed bridge, and has been constructed by segmental method.
The bridge is 426m long, 14.6m to 17.6m widths. The center span is 219 and both side spans are 102.7m long. This bridge has triple box-section prestressed concrete girder and H-shaped concrete tower. The girder height is constantly 2.3m and deck slab is 0.27m, lower slab is 0.165m, webs are 0.2m thick. In order to achieve such a slender cross section, $60N/mm^2$ strength concrete is used for the girder as well as external tendons are used for continuity tendons. Pre-cast are produced at the casting yard. 4 casting machines and 100ton gantry crane are equipped and maximum 80 segments can be stocked in this area. The segments are hoisted with the gantry crane and lifting frame are placed on the transport car, then transported underneath erection trusses. The erection trusses are placed just above the entire bridge before erection works. The segments are lifted with lifting frames and erection start from pier head segments simultaneously. The construction of caissons were started on April 1996. The super structure has been completed by the end of 1998.

2. Results and Conclusion

Prior to beginning the construction, both a landscape study committee and a technical investigation committee were organized and from the point of landscaping as well as designing and in-situ construction view point, so much study and investigation has been conducted.
As a result, the 3 spans continuous prestressed concrete cable stayed super structure has been selected and recommended expecting that this super structure would become a landmark at this area. Also, those new technique or technical skill such as a using of $60N/mm^2$ strength concrete, segmental construction method were adopted.
All of these new trials has been successfully accomplished.

Block Panel Structures with the Prestressed Membrane

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Abstract

During the last 15 years in Russia carrying metal structures of the coverings of the new type appeared to become widely spread: space block panel systems, in which prestressed membrane works as a part of the block's chords and as a boarding surface simultaneously.

The main element of the prestressed coverings of this type is a panel of the maximum transport overall dimensions factory of the ultimate factory readiness. This panel is presented as a tough frame with the membrane tightened on it (thickness - 1--2,5 mm).

In accordance to constructive shaping such a panel can work as a part of the covering on the squire, rightangular, round, elliptic or other more complex plane. Up to the present time similar coverings are carried out in the form of spans from 24 to 84 m. Project elaborations show its rationality for the spans up to 120 m, including the production buildings with a suspended cranes.

The usage of the given structures enables to solve the following problems: the uniting of carrying and boarding functions; factory elaboration of the large elements on the automatised lines; industrial erection up to the ultimate factory readiness in the form of large elements; reducing of the expenditure of the steel on the covering at the expense of excluding boarding construction proper.

The choice of the way, consequence of erection and the level of preliminary stress are accounted for by calculating and depend on the possibilities of elaboration, conditions of erection and exploitation.

When designing elements of the prestressed steel structures of the given type one has to take into account not only the norm requirements, but also the peculiarities of constructing, production and erection, described below.

The realisation of panel prestressing with a thin sheet plating leads to combining the carrying and boarding functions.

The choice of the method and the level of prestressing is accounted for by the calculation and the production considerations.

The design of such structures must contain, firstly, the scheme of works production, that are connected with the panel elaboration and their prestressing, secondly, information on the control of the level of prestressing, and also calculations needed.

In the Melnikov Central Research and Design Institute of Steel Structures complex experimental--theoretical investigations are made. The present report is devoted to the original methodics of the calculating of the prestressed membrane and the structure as a whole on the stages of elaboration, erection and exploitation.

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Improving Quality of Post-Tensioning Tendons with Plastic Duct

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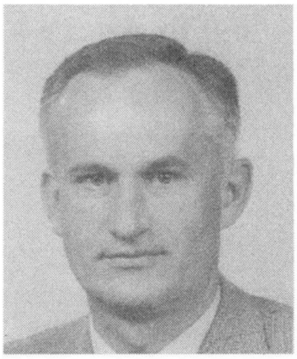

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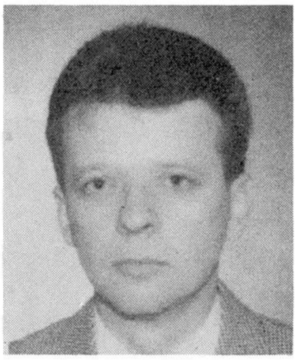

Summary

While the durability of post-tensioned structures is generally good, corrosion problems with post-tensioning tendons have occasionally been reported. A thick walled and tight plastic duct system has been developed, which offers extremely good corrosion protection. In this paper experiences and evaluations of site measurements are presented, which were gained when working with plastic duct for the first time on German construction sites (Ludwig-Erhard-Haus in Berlin and HTS – Bridge in Siegen).

Keywords: Post. tensioning ; quality ; plastic duct ; tendon elongation ; site measurements.

1. Introduction

Post-tensioned tendons in steel ducts are protected against corrosion by concrete cover and grout. With proper structural detailing and careful execution of the construction work on site, the concrete cover will have sufficient thickness and the material properties of grout and mortar will be of high quality. While the durability of post-tensioned structures with steel duct is generally good, corrosion problems with post-tensioning tendons have occasionally been reported [1].

In order to provide an enhanced corrosion protection for post-tensioning tendons, a plastic duct system was developed by a post-tensioning company [3]. Plastic ducts offer greatly increased corrosion protection for tendons and a higher resistance against fretting fatigue compared to conventional steel ducts. The friction coefficient for plastic ducts is lower than the friction coefficient for steel ducts. On one hand plastic ducts offer advantages for practical applications because of their low weight and the convenient duct couplers, on the other hand special care has to be taken during the placing of the duct and specifications have to be closely followed.

Investigations of the bond behaviour, the friction coefficient, the influence of the ten times higher thermal expansion coefficient of polypropylene in comparison to concrete, injectability and fretting fatigue have been compared to experimental results of steel ducts in [5].

In the eight page version of this contribution experiences are reported which were gained when working with plastic ducts for the first time in Germany.

2. Plastic Duct for Post Tensioning Systems

According to the German certificate of approval [2], plastic duct is available with round cross-section with inner diameters of 59, 76 and 100 mm for up to 22 strands of 0,6“ (Fig. 1) and with flat oval cross-section for up to 4 strands of 0,6“ (Fig. 2). The material used for the production of the ducts is polypropylene.

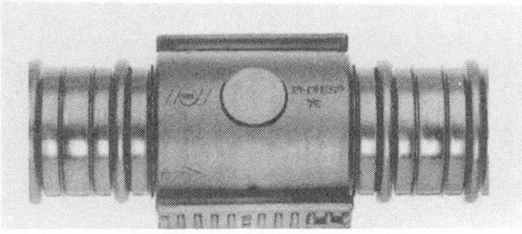

Fig. 1 Round plastic duct with coupler

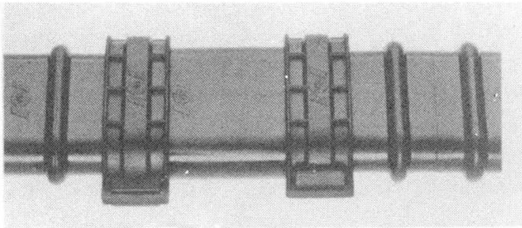

Fig. 2 Flat plastic duct with coupler

The design of post-tensioned structures with plastic duct can follow exactly the same principles as for structures with corrugated steel duct. Friction losses during stresses can be determined with the conventional method

$$P_{(x)} = P_o \cdot e^{-\mu(\alpha+\beta \cdot x)} \qquad (1)$$

In the certificate of approval [2] design values for μ equal to 0.14 and β equal to 0.3 are suggested.

For ultimate conditions rigid bond between post-tensioning strands and concrete may be assumed which allows to develop the yield strength of the post-tensioning strands at critical sections.

3. Recommendation

Laboratory experiments and experiences from using plastic ducts on site have shown that the duct system [3] will remain tight if design recommendation on maximum support distances and minimum radii of curvature are followed. With plastic ducts as a tight barrier the corrosion protection of post-tensioning tendons is greatly improved. Plastic ducts should therefore become the regular choice for designers and are strongly recommended for tendons which might be highly exposed to corrosion like transverse tendons in bridge decks and tendons of parking garages.

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Steel Bridges on the Peripheral Motorway, Ankara, Turkey

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Summary

Erection aspects of steel orthotropic bridges recently constructed on the Peripheral Motorway around the Ankara city in Turkey are discussed in this paper. Two bridges having a main span of 147m have been erected by method of launching from two banks with further locking in the center span. And one bridge having a main span of 105m has been launched from one side using a nose. These three bridges have been built using the established in Russia technologies for steel superstructures assembly and incremental launching. A thorough assessment and review of each erection stage in the design ensured a reliable structural behaviour of permanent and temporary structures.

Keywords: bridges; erection; launching; steel; superstructure; locking; design.

1. Introduction

A final selection of the route alignment of the Ankara Peripheral Motorway necessitated three large bridges crossing Cubuk and Bayindir water reservoirs and Karatas valley. The Cubuk, Bayindir and Karatas bridges have total lengths of about 300, 400 and 600 m respectively. The steel box girders with orthotropic deck were adopted for all three bridges.

A special feature of the construction of these bridges is the erection of steel superstructures by method of incremental launching. Peculiarities of steel superstructure erection when launching is proceeded from two sides with a closure joint in the center of the main span and from one side using a nose are further discussed in details.

2. Project Description

The Cubuk bridge is a continuous three-span structure with a span arrangement of 73.0 x 147.0 x 73.0 m. The Bayindir bridge has a continuous five-span system with a span arrangement of 52.5 x 73.5 x 147 x 73.5 x 52.5 m. The Karatas bridge has a six-span continuous superstructure system which is based on 84.0 x (4 x 105) x 84.0 m spans. The bridge cross section accommodates dual carriageway, pedestrian footways and carry service cables.

The design of the superstructure was based on the normal Russian standards using loading as per AASHTO and special highway loading. The substructures were designed to the AASHTO standard. The bridges are located in a seismic zone and have to withstand seismic forces corresponding to a ground acceleration of 0.12g. The seismic design was carried out in accordance with the AASHTO-SDHB recommendations with some modifications for local conditions.

3. Fabrication, Transport and Assembly

Steel structures for Cubuk bridge were fabricated in Voronezh, Russian Federation. Fabrication for Bayindir and Karatas bridges were carried out in Dnepropetrovsk, Ukraine. The fabricated in the shops elements were first transported by railway, then on a ship over the Black Sea and at the end by road to reach their final destination at bridge sites.

For the Cubuk and Bayindir bridges assembly of half the length of each superstructure was carried out behind the north and south abutments. For the Karatas bridge the assembly of the superstructure was implemented behind one abutment only. After assembling the segments sequentially, the superstructure is launched out into the spans.

4. Erection by Method of Launching

4.1 Erection Design

To ensure a reliable structural behaviour of permanent and temporary structures, various problem areas were studied. These were examination the behaviour of girders during the process of launching, estimation stress levels in the structural components of steel superstructures and some others.

4.2 Launching from Two Banks

For the Cubuk and Bayindir bridges launching have to be implemented from two banks of the reservoirs. Then the launched superstructure halves have to be jointed in the middle of 147 m central span. This is a rather delicate operation which requires relevant accuracy and experience. The difference of temperature within the steel contour was an important consideration for locking operations. The superstructure "lock" joint was welded in accordance with the required sequence. After completion of welding works the kentledge was removed from the superstructure ends. The superstructure ends were simultaneously raised by jacks at the abutments while the lifting forces were controlled by manometers.

Compared to the Cubuk bridge, the locking of five-span superstructure of the Bayindir bridge required two temporary joints at the superstructure. When two superstructure halves were launched to their final position in the central 147 m span, the temporary joints were disconnected to allow superstructure position adjustment. Most of the operations were similar to those of the Cubuk bridge.

4.3 Launching from One Side

The Karatas bridge launching was implemented from one side. To reduce stresses in the launched superstructure, a launching nose was used for the superstructure. In addition deck orthotropic plates between the boxes and at side cantilevers were not installed at the "head" of the launched superstructure.

The strength analysis outlined some critical points at top of the deck in the last 84 m span. Therefore to reduce built-in stresses a special erection sequence for the top deck orthotropic plates was required.

5. Conclusion Remark

The construction of the Cubuk bridge was started in the mid of 1993 and completed in 1996. The construction of the other two bridges commenced a little later. The Bayindir and Karatas bridges were opened to traffic along with the relevant parts of the motorway in 1997 and 1998 respectively. All three bridges provide a landmark structures on the route which forms a part of the transportation system development in Turkey.

Prestressed Concrete Structures for the Future

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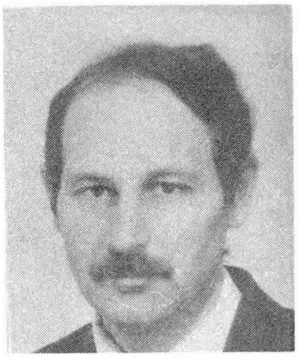

Mechyslav Chekanovych, born 1960, received his civil engineering degree from the Ukrainian Transport University in 1982 and PhD in Kiev State Technical University of Construction in 1993

Summary

Prestressed concrete structures of the future must have high strength, better quality and be environmentally friendly. Among them we can consider reinforced concrete elements made according to the "during-tensioning" method offered by the author. It is achieved due to compressing unset concrete mix during the operation of steel tensioning. The improvement of structure quality is provided here by concrete compaction, increasing cohesion and adhesion of the material. Adequate calculation apparatus has been developed. The research results were successfully used in the construction of a big bridge.

Keywords: pretensioning, post-tensioning, during-tensioning, concrete mix, column.

1. Introduction

The artificial environment created by man on the threshold of the third millennium, is characterized by a wide use of concrete. The dominant position of cement concrete in building practice is due to sufficient reserves of raw materials and relatively low concrete cost. The combination of positive properties of concrete and steel has ensured its leading place in bearing structures. The application of prestressing in concrete has allowed people to have relatively cheap, crack resistant, rigid and durable structures. At present, there are a great number of proposals as to the implementation of prestressing. The majority of them are well studied, and some of the best ones find practical application. Almost all of these suggestions can be classified into two groups according to the methods of steel tension: pretensioning and post-tensioning.

The possibilities of developing new and more effective ways of prestressing of reinforced structures in the frames of the two methods are in many aspects exhausted. Here we need a new qualitative transition to new concepts, beyond the existing prestressing methods, to set a precedent for fresh ideas and development.

2. New method of prestressing

The author has offered and put into practice the principle of prestressing transfer onto the freshly placed concrete mix of structures. In this case prestressing is made already at the stage of cement concrete components.

After vibrodynamic compaction, the placed unset mix is under compression of the steel prestressing force, and it hardens under the pressure. All this leads to the concrete mix compaction, the removal of water excess and air from the mix, to eliminating macro-and partly microdefects of the concrete structure, and to restraining destructive processes during concrete hardening. Steel prestressing is preserved, for after the compaction of the specially proportioned concrete mix, rather a strong and rigid skeleton of solid ingredients is formed, and the stressed steel is then fixed onto this skeleton (fig.1).

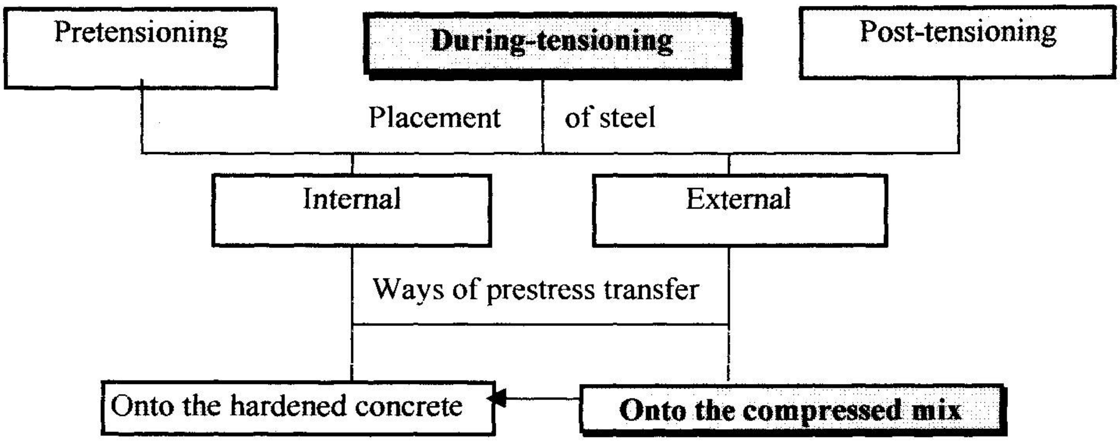

Fig.1. Extended scheme of methods of making prestressing in reinforced concrete structures

It is also possible to partially transfer steel prestressing onto the concrete mix. The realization of the new technology method of concrete mix prestressing became possible after the author had invented original movable forms and devices for full or partial prestressing transfer.

Considerable increase of the effect of uniform concrete compression, the elimination of undesirable initial stress in reinforcement is possible due to the application of movable steel bars proposed by the author. The bars are made in a special way. During the pretension these elements are shortened within the length of the structure. The concrete contacting the steel is compressed and reaches a high degree of compaction. A high quality contact is provided. Prestressing is transferred onto the concrete.

3. Production implementation

The level of research includes production implementation. At present, large 30-ton bridge elements of prestressed concrete made by compressing the unset concrete mix by the force of steel tensioning are successfully used in Ukraine.
Favoring practical application of the above mentioned elements was the device invented by the author, which provides reliable control over the quality of the compressed concrete directly in the product. Service observations of the reinforced concrete pillars produced according to the technology offered in the piers of the trestle part of a large bridge over the river Dnieper in the town Dneprodzerzhinsk (Ukraine) confirmed high quality of the structures compressed according to the "during-tensioning" method.