

Marina Rakočević¹, Miloš Knežević², Snežana Rutešić³, Nenad Ivanišević⁴, Boško Stevanović⁵

^{1,2,3}University of Montenegro, Faculty of Civil Engineering, Podgorica

^{4,5}University of Belgrade, Faculty of Civil Engineering, Belgrade

Construction Technology and Quality Control of Works on Atlas Capital Center

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With the arrival of foreign investors in Montenegro, a need for application of FIDIC international conditions of contracts emerged. These conditions define in detail the rights and obligations of the contractual parties in the construction process. In some issues these conditions do not comply with the Montenegrin legal system. This paper presents the organization and construction technology with special emphasis on the quality control and procedures for conducting internal and external quality control in the construction of a residential and business building Atlas Capital Center (ACC), which was contracted according to FIDIC Red Book.

Key words: structure, construction technology, method statement, quality control, Fidic

1. Organization of construction works

The construction works consist of several production processes. Through good organization and sequencing of activities it is possible to increase the productivity, taking into account the required quality and planned deadlines. Execution of works is conducted in the following stages: preparation, production/construction and taking over.

The preparation phase for the start of the works includes preparation of technical documentation, selection of the Contractor and selection of the Supervisor. This preparation phase includes the acquaintance of all participants with the technical and contract documentation.

The production or construction phase includes: preparatory construction works, construction and craft works, installation works, mounting of equipment and facilities etc.

The taking-over phase includes technical inspection and the beginning of the exploitation of the works and the start of the Defects Notification Period.

In each of the stated phases, the participants: Investor, Supervision and Contractor, have obligations and responsibilities which are regulated by legislation and contracts.

At the beginning of the project the Contractor, based on the mentioned documentation, performs an analysis of events and prepares plans. All significant events need to be followed by written documents.

Procedures of information flow are one of the first steps that should be prepared in the "production" phase of works. These procedures define the way the distribution and control of information will be performed. Modern means of communication allow for a faster flow of information and make communication more efficient. The participants in the project realization will submit the list of mail addresses for external communication.

2. General information about the Atlas Capital Center

The implementation of the construction contract closed on the basis of the FIDIC Red Book, operation, procedures and documentation which define and verify the key events during construction are described on the example of Atlas Capital Center (ACC).

The contract for the construction of an exclusive residential and business building ACC in Podgorica was signed according to FIDIC'S Conditions of Contract for Construction, Red Book. Investors of this grandiose building are the Atlas Group and the Capital Investment, while the Contractor is the Bitermo Mng Ltd. construction company whose parent company is Bitermo Ltd. from Portorož. Project management, cost management and supervision are entrusted to the company Mace d.o.o. which is part of Mace Group.

The basis of the building covers an area of about 10,112.5 m². The building has four underground floors and, depending on the part of the building, six, nine or eleven above-ground floors. The area of the underground part of the building is 40.450 m², while the total area of building is about 90.000m². The underground part of the building is shaped like a triangle and is constructed as one structural unit. In the underground part, three floors are designated for garages and one floor is for commercial purposes. The above-ground part consists of seven structures out of which three are designed for business activities and four are for residential purposes.

The building is designed in accordance with the highest standards, with materials and equipment of excellent quality not only in the technical and technological terms, but also in terms of design.

3. Technology of Works and Method Statement

The choice of methods and the description of the technological processes for construction, with an appropriate selection and sizing of work resources, is the first step in determining the method and sequence of work, 3,4,5,6. The technology of works needs to be in line with the technical and other necessary building site documentation. Also, it is necessary to comply with the technical requirements for construction works and technical specifications for materials and equipment which will be installed.

The Contractor defines the technology of works in accordance with available:

- machinery and means of work,
- material,
- workforce,

in order to achieve their optimum usage, required quality of works and time for completion. Based on the above, flow diagrams and process charts are defined.

The construction of reinforced concrete structure of the ACC is an example of good organization and technology of works. Using well-defined technological steps, 9,581m³ of concrete and 735 tons of reinforcement, were successfully built into the foundation slab during the summer time in only 75 days, at extremely high temperatures. On the four underground floors 15,660m³ of concrete and 2,223.9 tons of reinforcement were built into the structural elements during a period of four months. With good organization and proper selection of technological steps, in the above-ground structural elements of ACC complex, about 21.200m³ of concrete and 3.372 tons of reinforcement were built in. The works on the structure were completed within the planned time, meeting the designed quality.

At the beginning of the project, before the implementation phase, general technology of works on the concrete structure, in line with the Concrete Design, was given through the Method statement for the structure. During the execution of works, there was a need for a more detailed Method statement for certain positions. A detailed description of the construction technology for the reinforced concrete structure was made according to the types and positions of works. A detailed description of technology was defined for carpentry, reinforcement and concrete works.



Figure 1: Preparation for concreting of reinforced concrete slab, pipes of stationary pump

The Method statement for the carpentry work included a list of resources for the work, the number of suitably qualified staff, and the organization chart, the process of setting formworks for certain positions, a detailed schedule, quality control and applied safety-at-work measures.

The Method statement for reinforcement works included the number of reinforcement preparation plants, the number of workers with data on their qualifications, the organizational chart, the transport of materials, the time schedule of production and the accomplishment of works, the method of installing, quality control and applied safety-at-work measures.

It was necessary to define the technology of concrete works in detail in order to prevent possible problems during concreting. Description of the method included the special procedures of production, delivery to the site and placing of concrete. Due to large quantities of concrete that had to be placed the Method statement defined special control procedures:

- during the production of concrete,
- of concrete transported to the site,
- of concrete on site of incorporation and
- of curing of incorporated concrete.

A more detailed description of the placing of concrete was needed because of the size of the building (the basis around 10,112.5 m²), and extremely high summer temperatures. In case of extreme situations specific procedures and alternative solutions were defined. Figure 1 shows the means for transporting concrete to the place of incorporation into the structure, while Figure 2 shows the progress of works on the concrete block of the structure of business parts of ACC.

According to the positions that are concreted, special method statements were defined for the foundations, the side walls, the walls, the cores, the columns and the floor slabs.

The complex geometry of the building, floor heights, the overall height of the building and the thickness of the floor slabs demanded a preparation of a separate method statement for the slabs scaffold. This method

statement included the static calculation of supports for the above-ground floor slabs. Due to a large number of supports that were needed on the building, in order to prevent disasters due to damage of supports (geometric and material nonlinearities), and in order to receive horizontal forces arising during the concreting, the supports were linked by brace of tubular scaffolding. This way of linking supports was very effective.

4. Quality control

Quality control during the construction works should be organized and implemented in levels, with defined responsibilities and obligations of each participant. Organization of quality control is proposed by the Contractor, by submitting the Quality Control Plan for each working position individually. After receiving the approval from the Supervisor, the Contractor implements the plan.

The Quality Control Plan includes measures and procedures for:

- review and audit of Quality Control Plan,
- purchase and control of materials and equipment,
- control of transport and storage of materials and equipment,
- control of documents,
- inspection and certification,
- control of performance,
- implementation of regulations and standards,
- communication and correspondence,
- problems of non-compliance (in case of unsatisfactory quality),
- solving the problem of non-compliance,
- control of the Subcontractors,
- approval for procedures and measures.

Quality control is implemented through internal and external quality controls. Internal quality control is conducted by the Contractor with the inclusion of the control procedure of Subcontractors. The Contractor appoints a person, the quality manager, responsible for performing the Quality Control Plan in an efficient and appropriate manner. External control was conducted by the Supervisor. The Supervisor gives the approvals to the proposed Method statements and Quality Control Plan.



Figure 2: Works in progress on concrete blocks on the business part of ACC

Subcontractors were involved in the works on the foundation slab. The Subcontractors and the Contractor appointed persons to carry out internal quality control. During the external quality control of performed works the presence of the responsible person of the Contractor was required. The following procedures and types of controls were used during the quality control of the foundation slab of ACC:

1) Preparation for works on foundations:

Inspection of the foundation base is done by surveying methods of observation and measurement. Internal control includes daily checks by the Subcontractors and the occasional inspection by the Contractor. This position is a hold point for the Subcontractor and it requires a written permission by the Contractor to continue works on the next position. External control is occasional, associated with control of the accompanying documentation and control of compression module of the substrate;

2) Blinding concrete $d=8\text{cm}$, Grade MB15:

The inspection includes the control of surfaces, dimensions and elevations, as well as the quality control of blinding concrete, where the methods of monitoring, surveying and taking of concrete samples are applied in accordance with the Concrete Design. Internal control includes daily checks by the Subcontractors and periodical control by the Contractor. External control is occasional and involves controlling of the flatness, thickness and quality of blinding concrete – number of taken concrete samples;

3) Preparation of Bentofix waterproofing:

The control includes control of materials, positions and overlaps according to the detailed Method statement for this type of material where the methods of observation and measurement are defined. Internal control includes daily checks by the Subcontractors and periodical control by the Contractor. External control is occasional;

4) Acceptance of Bentofix waterproofing:

Acceptance of waterproofing is done according to the detailed Method statement for this type of material where the methods of observation and measurement are defined. This is a hold point for the Subcontractor, because the Contractor needs to perform a detailed inspection before the next position of works can start. By signing the “check” list the Contractor confirms that he has performed the control of this position after which the external inspection will be carried out by the Supervisor, who also, by signing or commenting the list of fulfilment of conditions, confirms that he has performed the inspection;

5) Blinding concrete $d=8\text{cm}$, Grade MB15 – protection layer of waterproofing:

The control includes the control of the surface, dimensions and elevations, as well as the quality control of blinding concrete, where the methods of monitoring, surveying and taking concrete samples are defined in accordance with the Concrete Design. Internal control includes daily checks by Subcontractors and a periodical control by the Contractor. External control is occasional and involves controlling of the flatness, thickness and quality of blinding concrete – number of taken concrete samples;

6) Installation of formwork and openings:

The control includes quality control of formwork, dimensions and positions where the methods of monitoring, measurement and surveying are defined in the detailed method statement. Acceptable criteria for approving are given in the Project documentation. Internal control includes daily checks by the Subcontractors and a periodical control by the Contractor. External control is occasional and involves controlling of dimensions, positions and quality of formwork;

7) Placing of the lower reinforcement zone:

The control includes quality control of reinforcement, dimensions and positions where the methods of observation and measurement are defined in the Project documentation. Acceptable criteria for approving are given in the Project documentation - drawings of reinforcement. Internal control includes daily checks by the Subcontractors and periodical control by the Contractor. External control is occasional and involves controlling of dimensions, positions and quality of reinforcement - visual control and control of attest documents. The control of reinforcement quality was also performed using the samples taken;

8) Mounting of anchors for the columns and walls:

The control includes quality control of anchors, dimensions and positions where the methods of monitoring and surveying are defined in the Project documentation. Acceptable criteria for approving are given in the Project documentation - drawings of reinforcement. Internal control includes daily checks by the

Subcontractors and a periodical control by the Contractor. External control is occasional and involves controlling of the dimensions, positions and quality of anchors - visual control and control of attest documents;

9) Placing of the upper reinforcement zone:

The control includes quality control of reinforcement, dimensions and positions where the methods of observation and measurement are defined in the Project documentation. Acceptable criteria for approving are given in the Project documentation - drawings of reinforcement. Internal control includes daily checks by the Subcontractors and a periodical control by the Contractor. External control is occasional and involves controlling of dimensions, positions and quality of reinforcement - visual control and control of attest documents. The control of reinforcement quality was also performed using the samples taken;

10) Final positioning and setup, preparation for concreting:

The control includes controlling of the position, stability and cleanliness of reinforcement and control of the equipment for concreting where the methods of observation and measurement are defined in the Project documentation, including surveying. Acceptable criteria for control are given in the Project documentation and Method statement. Internal control includes inspection by the Subcontractors and then inspection by the Contractor and then filling up the check list (list of fulfilment of requirements) for concreting and submission to the Supervisor. External control by the Supervisor is occasional;

11) Acceptance of the concrete block for concreting:

The control involves verifying the correctness of executed works where the methods of observation and measurement are defined in the Project documentation. The criteria for acceptance are given in the Project documentation. This is a hold point for the Subcontractor because the Contractor needs to perform a detailed inspection before the next work position can start. The Contractor, by signing the "check" list, confirms that he has performed the inspection of this position after which the external inspection is carried out by the Supervisor, who also verifies fulfilment of conditions for concreting by signing or commenting the list. If the Supervisor does not agree or does not sign the "check" list, the Contractor is obliged to remedy the given objections and then repeat the control procedure;

12) Concreting of concrete block for reinforced concrete foundation slab $d=90\text{cm}$, Grade MB30:

The control includes the quality control of concrete, dimensions and elevations, as well as the control of means for work. During the control, methods of monitoring and taking of concrete samples are applied in accordance with the Concrete Design. The Subcontractor performs the sampling of concrete with the Contractor's inspection. External control includes confirmation by the Supervisor of the above control procedures, especially for the quality of concrete and the number of taken concrete samples;

13) Curing of concrete:

The control includes the control of continuity of curing during the period set by the Concrete Design, all in accordance with the detailed Method statement for concrete works. Internal control by the Contractor is occasional. External control by the Supervisor is also occasional.

An integral part of Quality Control Plan of the foundation slab is a "check" list or a list of fulfilment of requirements for concreting the concrete block of the reinforced-concrete foundation slab. This list contains the work positions that are defined in the detailed Method statement which must be checked as stated above, and verified by the responsible persons of the Subcontractor, then by the responsible person of the Contractor, and in the end, by the Supervisor. Verifying the check list, the Supervisor confirms that he has performed the control in accordance with the Control Plan. The list contains the space for comments the Contractor and Supervisor may have.



Figure 3: Structure of the business units of ACC

During the execution of concrete works on the ACC facility a need for defining additional detailed inspection procedures for vertical concrete structural elements appeared. This inspection procedure was created as a consequence of inadequate control of the position of anchors for reinforced-concrete columns and walls by the Contractor. Due to this additional control successful measures for the remedy of the positions of anchors have been applied. The procedure includes the following control steps:

1) The Contractor is required to control the position of anchors for vertical elements immediately after the completed concreting of reinforced-concrete slab. Surveying records are submitted to the Supervisor on the same day when the concreting took place (regardless of whether the position of anchors is in compliance with the design, or there are major or minor deviations).

The recording includes:

- (a) Name of the element or part of the structure, floors, etc.;
- (b) Document Number and date of issue;
- (c) Name and signature of authorized person.

Depending on the case, the Supervisor independently and / or in collaboration with the Designer of the structure, decides on the measures for the recovery of the established deviations of anchor positions;

2) When the anchors are properly placed, the surveyors mark the position of the vertical elements;

3) Before inviting the Supervisor, the Contractor shall check the mounted reinforcement and other elements which should be installed. The responsible person of the Contractor controls whether this element is placed according to the designed documentation;

4) When the mounted reinforcement is properly placed, including the possible installation of structural stirrups and other devices that are designed to maintain the reinforcement in the designed position before and during the concreting, the responsible person shall notify the Supervisor that the concrete element is ready for control and approval for concreting;

5) The Contractor submits the "check" list of elements to the Supervisor with signatures of the responsible person of the Contractor. Lists with invitation for control of elements and approval for concreting shall be submitted daily to the Supervisor from 9:00 am to 10:00 am and from 17:00 pm to 18:00 pm. The Supervisor

performs the control in a short time, but not later than 24 hours after which he returns the lists to the Contractor;

6) On determining that the reinforcement and other elements are mounted correctly, the closure of formworks begins, all in accordance with the design and details, with prior application of special material for connection between old and new concrete;

7) The Contractor controls the set formwork and checks whether its position is structurally and geodetically correct (verticality and its disposition). After this check the responsible person of the Contractor signs the appropriate positions in the "check" list;

8) If all previous conditions are satisfied, the "check" list is submitted to the Supervisor at least 6 hours before the scheduled start of concreting in order to allow him time for his control of formwork and scaffolding. By signing of the "check" list the Supervisor approves the concreting;

9) If necessary, the Contractor shall, during the concreting, perform the geodetic survey and control of the formwork;

10) Formwork is removed not earlier than 48 hours after the completion of concreting of a vertical element, all in accordance with a detailed description of the position given in the Method statement;

11) On dismantling of formwork, the Contractor controls the verticality of the concrete element. In case of deviations, he immediately notifies the Supervisor in writing. After consultation with all parties (Supervisor, Designer, Contractor) the Supervisor makes a decision on taking appropriate measures to remedy identified deficiencies;

12) Before mounting of the formwork for plates above the vertical elements, an approval from the Supervisor is needed.

By applying the above control procedures the quality of these works on the ACC was raised to a higher level.

5. Safety-at-work measures

Important aspects of organization of works, which are associated with the preservation of life and health of workers at the construction site, are safety at work and enforcement of safety-at-work measures. Safety at work in civil engineering is very complex. One of the reasons is that the work is performed outdoors where, very often, workers meet with most unfavourable working conditions, such as: extremely low or high temperatures, rain or snow, noise, vibrations, dust, working at high altitudes or at great depths. etc. Also there is a constant risk of falls of workers from a height or falling of objects onto the workers. At the construction site the worker is constantly exposed to all these unfavourable working conditions, therefore, during the execution of construction works it is necessary to implement safety measures which ensure the safety of workers and others involved in the construction work process 7, 8. In terms of safety at work, construction works are legally regulated by a number of laws and bylaws.

The organization of work on the construction site should be such that it maximally reduces the possibility of injury of workers. The organizational documents of the Contractor have to envisage all the prescribed and in practice identified safety measures which should be implemented so that the workers would perform their work in a safe manner. The contract between the Investor and the Contractor regulates all the necessary safety measures in terms of their organization and implementation. Also, the contract regulates the mutual rights, obligations and responsibilities of the parties connected to safety at work.

The basic requirements of safety at work on the construction site are:

- a) working environment is designed, built and maintained with the application of safety measures against threats to life and health of workers,
- b) working conditions are adjusted to the physical and mental abilities of workers,
- c) method and organization of work are defined so that a worker works in an optimal position,
- d) electrical and other installations must be installed and maintained in accordance with technical regulations,

- e) in the working areas with chemical, physical and biological hazards all the parameters should be lower than the allowed limits,
- f) machinery, tools, equipment and other technical means of work should be designed, installed and used so that they do not endanger the safety of workers,
- g) personal protective equipment should be used as an addition to other appropriate protective measures.

The necessary measures of safety at work in construction industry are part of the Elaborate on the organization of the construction site. Having in mind that the injuries in the construction industry are usually a consequence of not applying the necessary preventive safety measures by the Contractor, as well as workers disobedience during construction works, it is necessary to constantly insist on the implementation of the prescribed safety measures. A delay in the implementation of safety measures cannot be allowed, and any individual irresponsibility must be sanctioned. It is necessary to include a safety expert in the supervision team.

During the construction of the ACC, as a result of non-compliance with the prescribed safety measures, there were a small number of minor injuries of workers employed at the construction site. There were no serious bodily injuries or life-threatening injuries. Experts for safety at work and other employees on the construction of the ACC had a significant role in the implementation of the prescribed health and safety-at-work measures which in turn resulted in the reduced number and severity of injuries and health problems at work.

Conclusion

With a good organization and an adequate choice of working methods, together with constant quality control of the execution of works, the required quality within the planned period of time is achieved. Using special procedures for the selection of materials, changes in the design and the contracted Bill of quantities result in a better control of the money flow and allow staying within the budget while meeting the designed quality.

The performed works on the structure of the residential and business building Atlas Capital Center is an example of good organization. During the period of 18 months 46,441 m³ of concrete and 6,331 tonnes of reinforcement were incorporated into the structure without any serious health and safety problems. The construction contract was signed according to the FIDIC Red Book. The area of the basis, geometry and dimensions of the building required not only preparation of a general Method statement for the construction of the structure, but also the preparation of detailed Method statements for all work positions. According to the Quality Control Plan an internal control was performed by the responsible persons of both the Subcontractor and the Contractor, while the external control was performed by the Supervisor. Quality control was verified by the "check" lists containing positions defined in detailed Method statements. The control of works organized in this way resulted in the achieved quality of the structure of the ACC which was completely in line with regulations and the project documentation.

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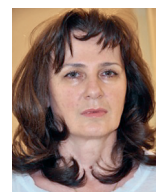
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About the Author

Marina Rakočević

University of Montenegro, Faculty of Civil Engineering, Podgorica
e-mail: marinara@ac.me

Marina Rakočević, PhD, Assistant Professor on the Faculty of Civil Engineering in Podgorica for the Theory of structure. Areas of interest for scientific research and professional work are real behavior of plates made from contemporary composite materials and quality control of constructions. She participated in the preparation of three scientific research projects. She is the author of 40 scientific research papers and articles. In practice, she participated as supervisor during the construction of significant projects in Montenegro, production of expert reports, revision of technical documentation, and technical inspections of buildings, etc.. From year 2010 she is the Vice Dean for education and the Chief of Laboratory for materials and constructions on the Faculty of Civil Engineering in Podgorica.



Miloš Knežević

University of Montenegro, Faculty of Civil Engineering, Podgorica
e-mail: milosknezevic@hotmail.com

Miloš Knežević, PhD, Associate professor at the Faculty of Civil Engineering in Podgorica, lecturer on Project Management at specialization postgraduate studies. He also lectures at the Project Management course on postgraduate studies at the Faculty of Tourism and Hotel Management in Kotor and the Faculty of Economics in Podgorica. He participated in a number of scientific research projects, published over 70 scientific papers in national and international journals. He participated in the preparation of over 120 design solutions, expert reports and technical inspections of facilities and buildings. From year 2010 he is the Dean of the Faculty of Civil Engineering in Podgorica and the Chief of the Applied Study Program in Construction Management.



Snežana Rutešić

University of Montenegro, Faculty of Civil Engineering, Podgorica
e-mail: snezandar@ac.me

Dr Snežana Rutešić, a Ph. D. CE, an assistant professor at the Faculty of Civil Engineering, University of Montenegro in Podgorica, in the field of building technology, organization and project management. The area of her particular scientific interest is quality management and information systems, which were the topics her master's theses and doctoral dissertations. She has published about thirty papers in this area published in monographs, international and domestic journals and many conferences. From 2010 she is vice dean for finance and a member of the Council of Technical and Natural Sciences, University of Montenegro.



Nenad Ivanišević

University of Belgrade, Faculty of Civil Engineering, Belgrade
e-mail: nesa@grf.bg.ac.rs

Nenad Ivanišević, PhD, MSc Civ.Eng, Lawyer, Assistant Professor at the Department of Construction Management, Faculty of Civil Engineering University of Belgrade. Areas of his special interest for scientific research and professional work are construction contracting, international tendering procedures and FIDIC conditions of contract. He is the author of a great number of scientific research papers and articles. He participated in the preparation and execution of a significant number of investment projects in Serbia and abroad. He is the Deputy Chief of the Institute of Construction Management at the Faculty of Civil Engineering in Belgrade.



Boško Stevanović

University of Belgrade, Faculty of Civil Engineering, Belgrade
e-mail: bole@imk.grf.bg.ac.rs

Boško Stevanović, PhD, is an Associate Professor at the Faculty of Civil Engineering, University of Belgrade, for the Timber and masonry structures. He has dozens of scientific papers published in the proceedings of conferences held in the country and abroad. Stevanović is the President of the Commission on standards and related documents in the field of timber and masonry, KS U250-5, 6, of the Institute for Standardization of Serbia. Since November 2006 he has been the associate dean of finance of Faculty of Civil Engineering in Belgrade.

