STRUCTURE AND QUALITY OF PRESTRESSED GIRDERS USED IN –CONSTRUCTION OF APPROACH VIADUCTS FOR 3rd BRIDGE OVER BOSPORUS

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Abstract 153 Viaducts, underpasses, overpasses and gully bridges are covered in the scope of motorway Project of Northern Marmara (including 3rd bridge over Bosporus Bridge). 150 of these have been constructed using pre-stressed girders while remaining 3 has been constructed employing incremental launching method.

3200 of the pre-stressed beams with heights of 90, 120, 150 and 180 cm and lengths up to 41 meters have been manufactured in precast facilities at Uskumruköy and Odayeri of Ilgaz İnşaat. In manufacturing of the pre-stressed beams, over 75.000 m³ C45/55 class concrete, over 15.000 tons of structural steel and 4000 tons of pre-stressing strands had been used. Compatibility of pre-stressed girders with the specification has been inspected constantly for 24 hours by the technical staff assigned in facility laboratories and working in shifts. As test load of 60 tons is applied to the pre-stressed girders selected by the technical personnel of Consultant Company in the presence of the committee, deflections occurring on the girders have been measured, and deflections have been measured again after removal of the loads on the girders. As the data obtained in performed tests are evaluated, it has been concluded that pre-stressed girders are compliant with technical specification for Highways.

Installation of the girders has been completed by launching girders which are present in machinary park of Ilgaz İnşaat and telescopic crane with lattice boom of 200, 300 and 650 tons of capacity.

The viaducts 6, 14 and 17 under the scope of the project have been completed by Ilgaz İnşaat - Freysaş Freysinet Joint Venture using incremental launching method (ILM). While incremental launching method is getting used for viaduct construction, lengths of the segments may extend up to 70 meters and therefore, it is possible to decrease number of piers.

1 Introduction

Total 3200 pre-stressed girders with varying lengths and types used for construction of the viaduct numbers V1, V2, V5, V7, V8, V9, V15, V16 on the European section of Istanbul. Also under passes and overpasses in the scope of motorway project (including the third bridge over Bosporus) have been manufactured in precast facilities constructed by Ilgaz İnşaat at Uskumruköy and Odayeri. Construction of the viaduct numbers V6, V14 and V17 had been completed by Ilgaz İnşaat-Freysaş Freysinet Joint Venture using incremental launching method (ILM). 45/55 class concrete has been used in manufacturing of pre-stressed girder and the segments used in incremental launching method (ILM).

2 Productions of Pre-Stressed Girders

Since the viaducts construction of which are undertaken are in different parts of the area subject to the Project and difficulty in accessing to the viaducts due to topographic structure of the region, pre-cast production facilities had been constructed by Ilgaz İnşaat at two different locations which are at Odayeri and Uskumruköy to ensure completion of the pre-stressed girders on scheduled time.

2.1 Concrete Batch Plant

In order to produce C 45/C55 class concrete to be used in manufacturing of pre-stressed girders, a concrete plant with a capacity of 120 m^3/hour and operating by automation system has been established in each precast production facilities. Because of using high strength concrete in production of pre-stressed girders, water/cement ratio had been kept relatively low and the chemicals in poly carboxyl ether class had been used. Since the temperature of cement provided to precast facility ranges from 80°C to 85°C, usage of it at this temperature had been accelerating the reaction. For this reason to take measures against formation of cold joint in manufacturing of pre-stressed girder, 3 cement silos, each with a capacity of 100 tons had been used. Beside this, a generator of 55 KWA has been installed to supply power to concrete plant in the case of power failure.

2.2 Water Steam Production Center

Saturated steam at 65°C used in pre-stressed girder has been generated by steam production center in the facility. As a precaution against failure of steam generator during the production, a spare steam generator of 2500 KWA has been kept at stand by.

2.3 Pre-Stressed Girders Production Facility

Hydraulic formwork systems, which vary up to 170 m by different types of pre-stressed girders, had been used. 3 production halls at Odayeri precast facility

and 2 production halls at Uskumruköy precast facility had been established for manufacturing of pre-stressed girders and 4 portal cranes, two with capacity of 20 tons and two with capacity of 40 ton had been utilized in different production phases at each field where production halls are located.

2.4 Reinforcement Preparation Station

The stirrups are one of the most important components in manufacturing of reinforcements for pre-stressed girders. In order to be able to increase speed and the sustainable quality of the production, the facilities had been equipped by Italian made, full automatic stirrup production machines

Stirrup manufacturing machines used in the facility have the features to work iron rods up to Ø16 mm in two lines, to bend iron rods with strength values up to 600 N/mm² and handle a capacity of 2.5 tons per hour. In addition, 10 iron rods bending and cutting machines used for preparation of iron components in varying forms in the pre-stressed girders have been utilized.

3 Preparation of the Concrete

75.000 m³ concrete of C45/55 class has been used in manufacturing of pre-stressed girders.

3.1 Components of the Concrete

Aggregate; 4 different aggregate types, one of which is natural sand compatible with the criteria in TS 706 EN 12620 Standard and 3 of which crushed aggregates of different grades have been used in composition of the concrete.

Cement; CEM I PÇ 42,5 R cement meeting criteria in TS EN 197-1 Standard has been used in production of the concrete.

Additive; New generation concrete chemical additives in poly carboxyl ether class meeting the criteria in TS EN 934-2 for C 494 type have been used for production of the concrete.

Concrete mixing and curing water; Water utilized in the facility has been used for concrete mixing and curing.

3.2 Determination of Concrete Design

In order to determine concrete design to be used in pre-stressed girders, concrete design report has been prepared as a result of mock up productions performed by R&D center of Yenice Precast facility of Ilgaz İnşaat. Considering that pre-stressed girder manufacturing activities are to be maintained under adverse weather conditions, 15 cm cubic samples taken from the trial productions performed in the laboratory have been kept at curing pool at temperatures of 20±2°C. Besides same samples had been kept under outdoor temperature conditions such as 0°C, 5°C, 45°C followed by concrete strength tests.

Design of the concrete to be used for manufacturing of pre-stressed girders had been determined taking the results obtained as a result of concrete design works carried out by ICA Quality Control laboratory. As a result of concrete trial

mixtures repeated with participation of the technical staff of Consultant Company, designs of the concrete to be used for manufacturing had been approved.

4 Manufacturing and Facility

4.1 Production of Pre-Stressed Girders

Production of pre-stressed girders had been performed in 4 steps as it is pointed below.

1st stage; Reinforcement components had been placed inside the form after the formwork for Girder was cleaned and lubricated. After driving the pre-tensioning strands with a length of 0.6" in the number specified in the respective project based on the type of girder, total 19.332 kgf tensioning force had been applied in 3 steps (110, 210 and 285 bar).

2nd stage: The concrete brought to production center by concrete mixer was poured into formworks in steps and settling of the concrete in the formwork was ensured operating 12 surface vibrators.

3rd stage: After completion of the production, steam curing had been applied in accordance with the criteria of TS 3648. Attention has been paid to make sure that the temperature of water steam was not above 65°C following percentage (%) of SO_3 in CEM I PC 42.5 cement used in the production.

4rd stage: As the compression strength for 15 cm cubic samples subjected to vapor treatment in the same environment with the girders was 41.5 N/mm^2, tensioning force of 19.932 kgf has been transferred to girder concrete by cutting pre-tensioning strands. The girders had been transferred to pre-storage area by ensuring the temperature of the girder reached to ambient temperature. As the value of 55 N/mm² required in concrete sample subjected to steam curing was achieved, the girders have been loaded to dollies according to installation schedule and sent to installation field. Stages of production for pre-stressed girders have been indicated in figures 1, 2 and 3.



Figures 1,2, 3: Production facility of pre-stressed girders at Uskumruköy.

4.2 Quality of the Concrete

In order to determine concrete quality used in pre-stressed girders and carry out R&D works, the laboratory established in precast facility had been furnished

with required test machines and equipment. Each step of the production had been checked constantly by technical staff working 24 hours in shifts.

Following studies have been performed by the technical personnel working in the laboratory:

a. Aggregates have been subjected to sieve analysis in weekly intervals and design of used concrete has been corrected accordingly.
b. Humidity percentage (%) of the aggregates has been determined in daily periods and design of used concrete has been corrected accordingly.
c. Tests have been performed to determine clay content in the aggregate using methylene blue test.
d. Since a part of the crushing facilities in Istanbul where the crushed aggregates are produced are close to coal mines, there is the risk of mixture of foreign materials containing carbon with the crushed aggregate. Carbon containing foreign materials contained in crushed aggregate decrease influence of poly carboxyl ethers and therefore leading to increase in water requirement of the concrete. Taking this issue into consideration, the aggregates brought to precast facilities has been controlled and crushed aggregates containing unwanted materials had been rejected without using.
e. Unit volume weights of set concrete have been determined and, they have been compared with theoretical unit volume weights in the concrete design report.
f. Taking curing –disintegration risk into account, water absorption ratios (%) of set concrete had been checked in weekly periods.
g. 6 of the 12 samples of 15 cm taken from the concrete used for production of pre-stressed girders had been subjected to the same steam curing with the girders. 3 of these samples have been tested before pre-stressing strands were cut, while remaining 3 had been tested before sending the girders to installation field. 6 samples not subjected to steam curing, had been kept in curing pool at ± 20°C to determine compressive strength values for 7 days and 28 days and meeting of the strength values required in the Project.

In order to determine quality of 3200 pre-stressed girders produced in Odayeri and Uskumruköy precast facilities using 75.000 m³ 45/55 class concrete, 34.400 cubic samples of 15 cm have been taken and compression strength had been determined. Results of concrete strength tests in between 1-4.03.2015 in Odayeri have been presented in Table 1.

Table 1: Concrete strength test results.

Production date	Compressive strength (N/mm²)				Production date	Compressive strength (N/mm²)			
	Hour	Steam curing	7 days	28 days		Hour	Steam curing	7 days	28 days
1.3.15	18	42,1	61,9	72,9	4.3.15	12	42,6	58,8	71,5
2.3.15	15	43	63,5	73,3	4.3.15	13	42,9	58,3	71,8
2.3.15	15	43,5	63,3	73,5	4.3.15	13	43	59,9	72,7
2.3.15	15	42,8	62,7	74,1	4.3.15	13	42,5	58,7	73,3
3.3.15	14	42,2	59,4	67,8	5.3.15	12	43	58,6	73,1

3.3.15	14	42,9	59,6	69,7	5.3.15	12	42,9	58,4	69,6
3.3.15	14	43	61,4	72,5	5.3.15	12	43	58,8	70
4.3.15	12	41,8	59,9	73,5	5.3.15	12	42,9	56,6	68
4.3.15	12	42,5	59,1	70,8	5.3.15	13	43,2	62,1	67,4
4.3.15	12	42	59,5	68,7	5.3.15	13	43	63	70
Average of compression strength values for 28 days (N/mm²)									70,7
Standard deviation (N/mm²)									1,97
Variation coefficient (%)									2,79

4.3 Loading Test

The results obtained as a result of loading test applied top re-stressed girders should meet respective criteria in technical specification for highways.

Loading tests for pre-stressed girders manufactured in Odayeri and Uskumruköy Precast facilities had been performed in 2 steps.

1st step; by applying a weight of 60 tons on one third (1/3) and two third (2/3) sections of the net opening of the girder of I 180 type, deflection had been measured waiting 15 minutes.

2nd step; deflection had been measured again after the weight of 60 tons imposed on the girders had been removed gradually.

According to technical specification of highways, minimum 90 % of the deflection amount measured as the entire test load was imposed should be achieved again after removal of the entire test load.

As the pre-stressed girders selected by the consultant company had been subjected to load test and assessed in the presence of the committee, it was observed that they had met the criteria in the technical specification for highways. The results of loading test applied to I 180 type girders used in V16 have been presented in Table 2.

Table 2: Results of loading tests applied to pre-stressed girders used in V16.

Girder no	K 139	K 40	K 130	K133
Girder length (m.)	41	41	41	41
Girder type	I 180	I 180	I 180	I 180
Production date	23.08.14	23.11.14	20.08.15	22.08.15
Test date	02.06.15	27.02.15	16.09.15	16.09.15
Concrete class	C 45/55	C 45/55	C 45/55	C 45/55
Compressive strength 7days (N/mm²)	60,5	56,4	62,8	61,5
Compressive strength 28days (N/mm²)	75,6	70,8	77,4	73,2
Applied load (Tons)	60	60	60	60
Starting time	10:20	09:45	13:30	10:35
Ending time	12:55	13:00	14:30	11:35
Air temperature (°C)	20	15,9	24	23
Return at the end of test (%)	98,4	99,6	99,9	99,3
Limit in technical specification	90	90	90	90
Result	Acceptable			

4.4 Installation of Pre-Stressed Girders

Telescopic crane with capacities of 200, 300 and 650 tons and boom lattice had been used for mounting of 3200 pre-stressed girders in varying types and lengths manufactured in the scope of the project. For viaducts where the crane had not been used, launching girders present in machinery park of Ilgaz İnşaat had been used. İnstallation of launching girders performed in V7 has been indicated in figures 6, 7.


Figures 6, 7: Views from the installation activities performed in V7.

5 Construction of Viaduct by ILM

Viaducts 06, 14 and 17 under the scope of the project had been manufactured / installed by the joint venture of Ilgaz İnşaat- Freysaş Freysinet by incremental launching method (ILM). Since it is possible to produce segments with lengths up to 70 meters in incremental launching method (ILM), it is possible to decrease number of piers.

In incremental launching method (ILM), segments with length up to 70 m may be cast in the cast area formed behind abutment. After obtaining required compressive strength, segment is tensioned and fixed by rear tension system and launching over the pier by jack systems. Views of works performed in Viaduct V6 using ILM are presented in figures 8, 9.


Figures 8, 9: Works performed in V6 Viaduct by ILM.

5.1 Comparison of ILM and Pre-Stressed Girders

Advantages of incremental launching method;

1. Since lengths and widths of the segments used in incremental launching method may be adjusted up to 70 meters it is possible to decrease number of piers in viaduct.
2. Because only one segment form is required cost of formwork is lower.
3. Consumption of steel and concrete is lower.
4. Since production of segment is performed beside viaduct, cost of transportation is not in question.
5. There is not a need to use high capacity crane for installation.

Disadvantages of incremental launching method;

1. Cost of infrastructure for preparing production yard is lower.
2. It is not possible to use produced segments for other viaducts.
3. If course of viaduct is extremely curved and inclinations in varying directions are in question, difficulties arise.
4. Because the quantity of concrete used in manufacturing the segments there is the risk of cold joints to occur in the concrete. (Approximately 250 - 300 m^3 concrete had been used for bottom slabs and side walls and 450-500 m^3 concrete had been used for slabs in the Project that we have undertaken.)

6 Conclusions

Ilgaz İnşaat has completed manufacturing of and mounting 3200 pre-stressed girders to be used for viaducts V1, V2, V5, V7, V8, V9, V15, V16 , under passes and overpasses on European side of Northern Marmara (including 3rd Bosporus) Motorway Project.

In order to ensure that manufactured pre-stressed girders are in compliance with the criteria in technical specification of Highways, technical personnel consisting of varying disciplines and professions and working in laboratory, foremen and qualified staff have worked for 24 hours a day in shifts.

Thanks to provision of production formworks, machineries and other equipment required in precast facilities on time and measures taken against adverse weather and geotechnical conditions, manufacturing and mounting of pre-stressed girders has been completed as scheduled.

Ilgaz İnşaat-Freysaş Freysinet Joint Venture had completed the viaducts 6, 14 and 17 by ILM. Thanks to all personnel who involved and gave extraordinary effort in all phases of the project from construction of the foundation until placement of the segments on piers.