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Prevention of Damages & Accidents in PSC I-Girders during Stressing & Erection Works

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Abstract: ***As the infrastructure boom in India is in continuous rising trend from last 2 decades, the works of Bridges, structures, viaducts, and elevated corridors for Highways, Railways & Metro are running throughout the country. In these last 2 decades there is very much development in the Construction Materials, Machineries, and Accelerated Bridge Construction Methods to improve the quality & to reduce the construction time.***
But even by using such advancement, there are frequent failures and accidents of PSC Girders are happening every year across the country, which causes loss of life, property, time and loss of faith on Engineer community from the society. Even though material, machinery, methods are became advance and modern, But Human efficiency, work knowledge, preciseness, effective supervision & quality control not improves to that extent.
Due to increased dependability on mechanization, improper supervision, negligence and ignorance in Quality control, not following the method statement & guidelines and poor workmanship these failure and accidents observed in maximum cases.
Keywords: Girder, Stressing, supporting, failure, erection.

I. SCOPE

This paper is mainly dealt with the PSC post tensioned I-girder (And PSC pre tensioned I-Girders & Segmental Box Girders for handling, lifting & erection works) failure causes & preventive measures for site related problems, workmanship, materials, methodology, stressing, erection, machinery, equipment, girder handling, shifting & lowering, concreting, de-shuttering etc. Design part of girder is not discussed here. Errors and shortcoming at the site is discussed here to highlight the issues of workmanship, knowledge, methods, preciseness, alertness; which can help the Bridge Engineers, Technicians & Foreman to omit the errors in various operations of girders.

A. Objectives

1) To develop awareness among the Engineers, Technicians & Foreman who engage in PSC Girder Casting, Stressing & Erection works.
2) Minimize the loss of lives, property and time of the nation.
3) Enhancement of Society faith on Engineer community.
4) Inclusion of important points in specifications, manuals and in safety codes.
5) Awareness for rescue arrangement & operation in case of emergency.

II. INTRODUCTION

As mentioned in Abstract above, Girder failures and damages are of many types. This mainly classified into following categories.

1) Major Failure Case.
a) Girder overturning, toppling & falling from its pre-final & final position.

2) Secondary Failure Cases.
a) Girder damages due to congestion of steel & ducts at End block.
b) Girder damages due to improper sequencing of concrete placing.
c) Girder failure due to uncompacted ground in launching and casting operations.
d) Girder damages due to improper casting bed.

3) Other Failure Cases.

a) Girder toppling due to uncontrolled side shifting.
b) Girder damages and failure during stressing operation.
c) Girder failure during erection and Transportation operation.
d) Girder failures due to sub structure failure.
e) Girder bending due to eccentric prestressing.
f) Damages due to faulty & unmatched stressing material & accessories.
g) Misc:- Girder tilting on casting bed due to buckling of ISMB, Bearing pocket not matching, Bearing grouting, Girder beds washed out by flood etc.

Let us take a detailed review of Major & Secondary Failure cases, Girder Damages and Failures, listed above as A & B.

A. Girder Overturning, Toppling & Falling from its pre final & final position.

This is the major case of PSC girder failure in our country. About 80% of failures are falling in this category. The main cause of this type of failure is due to improper supporting arrangement below girder soffit and insufficient inclined/ cross supporting and due to no interconnections between 2 adjacent girders.

Before moving forward for the further detailing, let understand the nature of change in forces at Girder end location, from before pre-stressing to after pre-stressing stage. Before pre-stressing the stress diagram is a combination of tensile and compressive forces. But after pre-stressing, net stress diagram changes to total compressive in nature and due to uplift (camber) of girder total weight of girder shifted to girder end location. Due to change in nature of net stresses at Girder end location, the girder becomes unstable and requires firm supporting arrangement to Girder support (end) location at bottom, at sides and requires interconnections between adjacent girders till casting of cross diaphragms for that set of girders. Even due to gusty wind impact or due to monkey jump, these girders may fall due to insufficient supporting arrangement.

1) Failure Causes

Failure in this category caused mainly due to

a) negligence in supporting arrangement of girders,
b) poor supervision during supporting,
c) Improper temporary interconnections between adjacent girders.
d) Entry & movement of unskilled workers in supporting area without Supervisor.
e) Girder directly over bearings, with full load on Bearings.
f) Machinery and equipment movement below & around the girders causing touch and vibrations to girder system.

➢ *Recent Failure History & Deaths in Accidents*

In the recent Indian history following are the major Girder failure cases and accidents and causalities happened due to failures.

- Varanasi Flyover accident on 15 May 2018, Death Toll 18 Nos.
- Anakapalli NH-16 Flyover collapse on 6-July-2021, Death Toll- 2 Nos.
- Kendrapada Odisha Gobari River Bridge Girder collapsed on 15-Mar-2023, No causalities.

➢ *Photographs of Failure.*

Fig 1.1:- Anakapalli AP NH-16 Flyover Girder Collapse 0n 6-Jul-2021

Fig 1.2:- Varanasi UP Flyover Girders collapse on 15-May-2018

2) Remedies

a) All supporting work shall be carried out under strict supervision and control of experienced Engineers, Supervisors.

b) Not a single support shall be removed or relocate, unless the permission granted by Engineer-in-Charge. This is one of the main cause of girder toppling.

c) When girders are cast-in-situ over a staging (At required level or at higher level), girder truss, precaution shall be taken for carefully removal of shuttering material under strict supervision, after prestressing & gap formation between girder soffit and shuttering top.

d) Method statement shall be strictly followed.

e) All girders shall be firmly placed over wooden blocks. Wooden blocks placed below Girder soffit and diaphragm soffit. Even if girder placed over bearing, these wooden blocks packing required.

f) Check the wooden blocks firmness by striking the ball pin hammer on blocks. After hammer striking ringing sound shall appear from the blocks.

g) Till casting of diaphragm all girders shall be interconnected by connecting/ welding rods to dowels of diaphragm of adjacent girders.

h) Placing and tack connecting the Steel Beam or Channel to shear connectors of the PSC girder and adjacent girder.

i) Placing and fixing the inclined supports (Struts), forming a cross frame at location between girder end portion to girder tapering portion.

j) During following all above steps between 5 to 9, care shall be taken that Plumb of Girder maintained, and working passage shall be available over cap for man-material movement.

k) No vehicular movement and pedestrian movement shall be permitted below the girders till casting of permanent diaphragm by concreting.

l) After casting of diaphragm by concreting, all supports and wooden blocks shall be carefully removed. Except wooden blocks below diaphragms.

Above arrangement are shown in following photographs:

Fig 1.3:- Supporting arrangement of PSC Girdes (3 Photos)

B. Girder Damages due to congestion of steel and ducts at End Block.

PSC Girder End Block is most congested part of girders. Due to various types of Multilayer mesh behind Anchor cones, at bearing location, Sheathing ducts, dowels of diaphragm, this girder end block portion become congested. Further steel bar overlaps and other unwanted ducts make it further congested and due to very high compression zone, damages of Anchor cone puncturing, Anchor Head insertion of concrete skin removal are occurred.

In one case extra ducts were inserted by Site Engineer for the provision of bearing top sleeves grouting. Due to these ducts cavity forms and hollow portion remain inside the girder resulting in insertion of Anchor Head inside girder during stressing. This effect & effect due to cavitation is shown in following photos.

1) Failure Causes

a) Congestion & lapping of steel at End Block portion.

b) Provision of unwanted ducts within End Block portion

c) Improper placing, sequencing, vibrating & curing of Girder Concreting.

d) Concrete slurry leakage through shuttering *joints.*

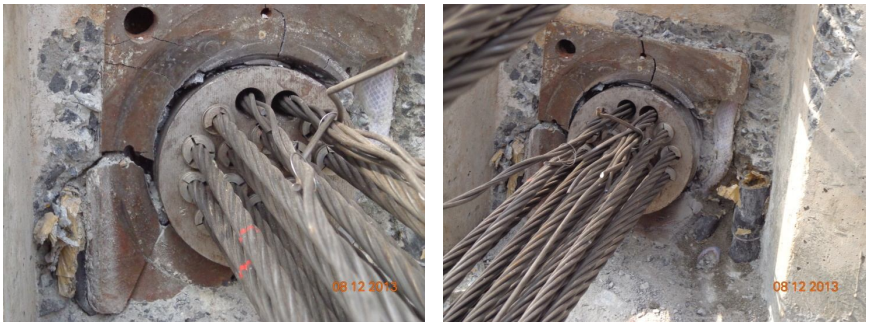

Fig 2.1:- Failure due to cavitation & grouting ducts (Anchor Cone Puncture)

2) Remedies

a) Lapping of steel shall not be provided in end block portion.

b) Other than sheathing, no ducts shall be provided in end block portion.

c) During concreting utmost care shall be taken for placing, sequencing, vibrating & curing of concrete. Form vibrators must be additionally used.

d) Before stressing cavitation, honeycombs around anchor cones and in end block portion must be ensure by hammer ringing test. If any cavitation or honeycomb detect, then grouting of concreting with suitable material must be carried out prior to stressing.

e) Additional MS square plate can be provided after approval from Engineer-in-Charge.

C. Girder Damages due to improper sequencing of concrete placing.

Concrete sequencing and placing is very much important for Girder concreting. Now days for long girders and for cast-in-situ girders, concrete placing is mostly carried out by Concrete Pump, Boom Placer and Mobile Tower Crane. By using the above machinery utmost care shall be taken that, concrete shall be poured and placed in layer from. No heap of mix shall be deposited within mould. In one of case of major failure, it was observed that contractor deployed 2 nos of mobile tower crane and layer sequence was not strictly followed. Due to which slurry and mortar get deposited in the middle portion of girder. Appearance of girder was very good after deshuttering, but during final stage stressing girder cracks & broke at midsection due to very low flexural strength.

Fig 3.1:- Crushing of concrete at weak flexural zone due to insufficient conc strength

1) Failure Causes

a) Improper pouring sequencing, placing and vibrating the concrete.

b) Holding pipe of pump/ boom placer or mouth of concrete bucket over the steel reinforcement resulting in segregation of course aggregates from concrete mix.

2) Remedies

a) Proper pouring sequencing, placing & vibrating of concreting strictly followed.

b) Pump/ boom placer pipe & concrete bucket mouth shall not hold over the steel reinforcement, to avoid the segregation of concreting.

c) Strict concrete quality control shall be followed.

D. Girder Damages due to Improper Casting Bed.

During stressing due to application of high compressive stresses, girder tends to hogging and after full stressing upward deflection of girder (Hogging) is observed at mid-section, and about 70% of girder length remains unsupported due to thus upward deflection. Hence complete girder load came at end block portion of the PSC Girder. Due to this excessive load at end block, end portion of girder tends to move downward in casting bed. If casting bed is rigid at ends, then skin portion of girder soffit and edges cracked, which damages the girder. Sometimes anchor cones get affected in this stage. Cracking & damages due to this cause are shown in photograph.

1) Failure Causes

a) Providing rigid casting bed at End Block portion of the Girder.

2) Remedies

a) Providing semi-rigid or flexible bed at End Block portion of the girder.

b) If rigid bed provided for casting, then prior to stressing convert the End Block Bed into semi-rigid or flexible type by wooden blocks.

Fig 4.1:- Removal of Girder Concrete skin due to Rigid casting bed at End Block portion.

E. Girder Failure Due to Uncompacted Ground in Girder Casting and Launching Operations. (Staging & Platform Failures).

In this type of failure, it occurs due to insufficient compacted bed for casting beds, staging platforms and ground supported launching platforms. Under beneath layer of beds may be loose, saturated, cavitation, hollow or weak pipe lines below staging are the main reasons. Following are the cases where such failure occurred in recent history.

- Hyderabad flyover failure on 09/09/2007 causing 20 deaths.
- Toppling of segment during sliding in West Bengal on NH-16, due to settlement of platform support.

1) Failure Causes

a) Insufficient compaction of beds for casting, staging & launching platforms.

b) Unknown presence of pipe lines, storm water drainage, drainage tunnels etc.

c) Water leakage below beds.

2) Remedies

a) Ensure the desired compaction for all ground layers.

b) Identify the underground ducts, pipelines, drainage lines and prepare the appropriate plan to safeguard the staging from settlement.

c) There shall be no leakage or underground flow of water below the bed layers.

Fig 5.1: (a) Hyderabad Flyover accident in 2007 due to failure of staging. (b) Ground supported launching arrangement before staging failure on NH-16.

Fig 5.2:- Segment erection failure due to settlement of uncompacted bed.

III. CONCLUSION

By reviewing all above case and review of failures in past history, It is concluded that Major failures are occurred in case no. 1 by overturning & toppling of girders. This is mainly happened due to negligence, unauthorized removal of supports, uncontrolled supervision and not following the sequences & method statement properly. It has observed that starting phase of work is being carried out in a controlled manner & in presence of experienced Engineers, but later stage will pass on to second level and many times no experienced team available for supervision in the later stage.

Secondary failures mainly are staging failure, Stressing failure due to cavitation, honey combs in end block portion of Girder and inappropriate strength of Girder concrete. These failures are discussed above as case no. 2, 3, 4 & 5. All the above failures can be avoided by confirming the site team qualification, experience, strict quality control & decision making ability. Every Girder casting, stressing & erection shall be carried out precisely & with full concentration. Early risk analysis of the work will provide the knowledge of material and equipments required at emergency. Check list of all important stages shall be prepared and get certified from the concerned authority.

Bottom line conclusion is these major failures can be prevented by Strict Supervision, Strict Quality Control, Experienced Team & workers, Implementation of sequence & method statement and proper handling of Girder stressing & erection works.

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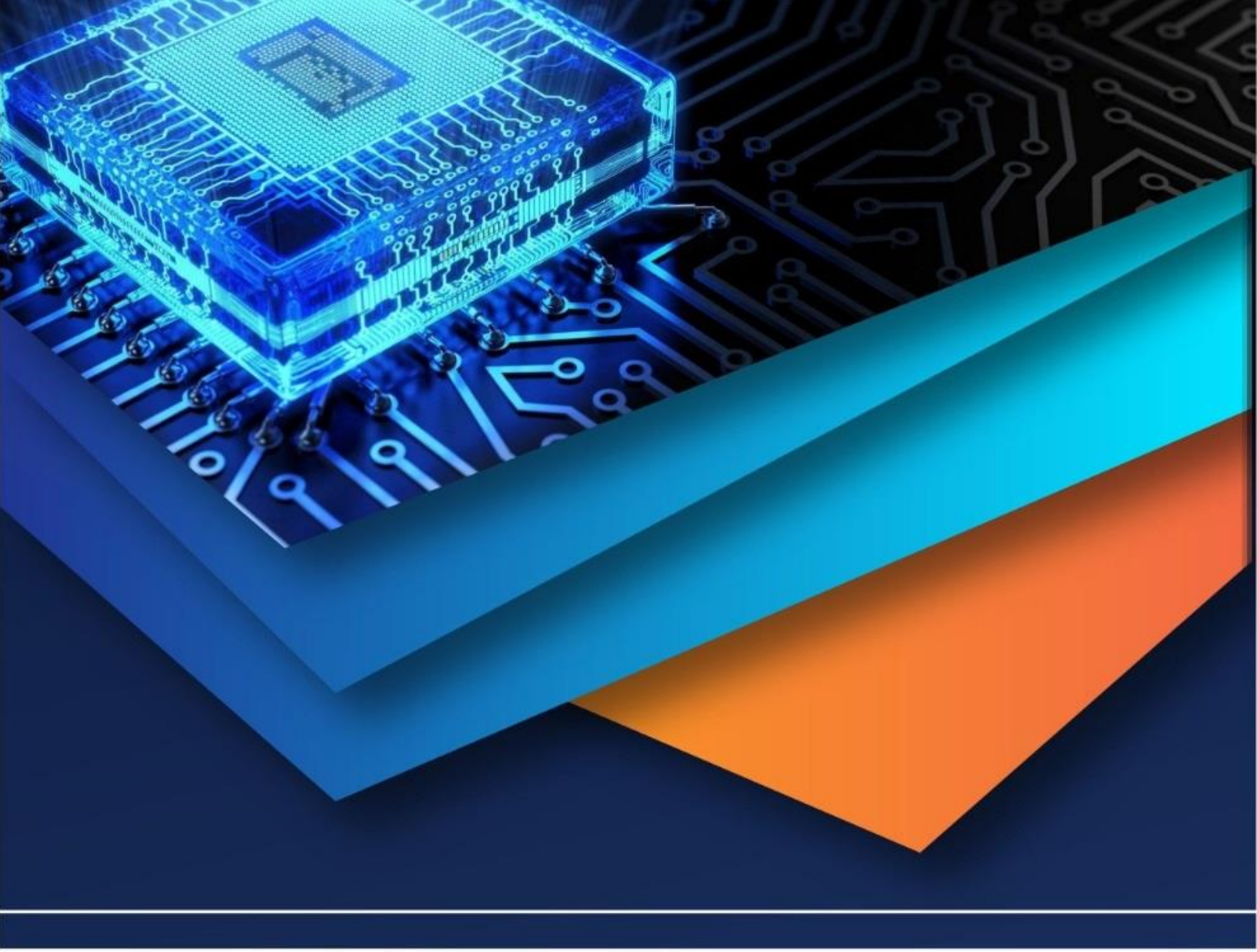

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