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GUIDELINES FOR CONSTRUCTION OF PRECAST CONCRETE SEGMENTAL BOX CULVERTS

INDIAN ROADS CONGRESS
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(As on 23.06.2017)

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26	Sheokand, Balbir Singh	Executive Engineer, PWD Haryana
27	Singh, Nirmaljit	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
28	Singh, Pawan Kumar	GM, 3M India Ltd.
29	Sinha, A.V.	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
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38	Verma, G.L.	MD, Engg and Planning Consultants Ltd., New Delhi

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3	Kandasamy, C	DG(RD) & SS (Retd.), Ministry of Road Transport and Highways, New Delhi
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1	President, Indian Roads Congress	(Pradhan, N.K.), Engineer-in-Chief cum Secretary, Works Department, Odisha
2	Director General (Road Development) & Special Secretary to Govt. of India	(Kumar, Manoj), Ministry of Road Transport and Highways, New Delhi
3	Secretary General, Indian Roads Congress	Nirmal, Sanjay Kumar

GUIDELINES FOR CONSTRUCTION OF PRECAST CONCRETE SEGEMENTAL BOX CULVERTS

1 INTRODUCTION

The draft "Guidelines for Construction of Precast Concrete Segmental Box Culverts" was first taken up by the Embankment, Ground Improvement and Drainage Committee (H-4) of previous tenure i.e. 2012-14. Later, the H-4 Committee was re-constituted for 2015-17 and the draft was deliberated in a series of meetings. The H-4 Committee finally approved the draft document in its meeting held on 30th September, 2015 and decided to send the final draft to IRC for placing before the HSS Committee.

The Composition of H-4 Committee is as given below:

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Nirmal, Sanjay Kumar	.....	Co-Convenor
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Ex-Officio Members

President, Indian Roads Congress	(Pradhan, N.K.), Engineer-in Chief cum Secretary, Works Department, Odisha
Director General (Road Development) & Special Secretary to Govt. of India	(Kumar, Manoj), Ministry of Road Transport & Highways

Secretary General,
Indian Roads Congress

Nirmal, Sanjay Kumar

The Highways Specifications & Standards Committee (HSS) considered and approved the draft document in its meeting held on 23rd June, 2017. The Council in its 212th meeting held at Udaipur on 14th and 15th July, 2017 considered and authorized Executive Committee of IRC to look into matter in consultation with respective Convenors of Technical Committee before its publishing. The Executive Committee in its meeting held on 7th August, 2017 considered and approved the same document for printing.

1.1 Precast concrete segmental box culverts are one of the most versatile and cost effective pre-cast concrete products, meeting the needs of fast paced construction projects. Flexibility in design and ease of placement at site leads to cost savings. The uses for pre-cast concrete segmental box sections are endless. They can be used for underpasses, service tunnels, subways, bridges, stream culverts, cattle pass and so on. These guidelines are applicable for Precast Concrete Segmental Box Culverts (PCBC) only. A Precast Concrete Segmental Box Culvert (PCBC) is an easily installed conduit used to provide passage for roads, pathways (or) flowing water (e.g. streams, storm water or drains) underneath roads, railways or embankments. Precast concrete segmental box culverts are being used in many countries including India. With modern and mechanized box culvert production facilities, one can produce over 40 - 60 m length of culvert section per day.

1.2 Precast concrete box culvert segments are most frequently manufactured and delivered captive or commercially as a finished section of required shape. Larger box culverts that cannot be transported as a single unit are constructed from two 'U' sections for on-site assembly. Sometimes two 'L' shapes and in between 'T' shapes are also being used. These are provided with rebated joints/V notched to allow sections to be laid open or sealed. Precast Concrete Box culverts may be even provided with precast wing walls and head walls.

1.3 Other components that may require precast elements include the following:

1.3.1 *Precast Concrete Wing Walls*

Wing Walls are retaining walls placed at the entrance and exit of a box culvert. The walls are sloped to match contours of the approaches. Wing walls help to form and protect the ends of the box culvert and are designed and manufactured to match precast culvert specifications and ground conditions.

1.3.2 *Precast Concrete Head Walls*

Head walls also known as head beams or face walls are typically located between wing walls at the end of the box culvert. These walls serve to retain soil above the top slab in order to form and protect the culvert entrance and exit.

1.3.3 *Toe Walls*

A low wall built at the bottom for providing embankment stability and to prevent scour at the toe of the embankment.

1.4 Advantages of Precast Concrete Segmental Box Culvert

Precast box culverts have the following main advantages:

i. The time span of entire construction of conventional culvert: comprising of casting base slab, shuttering/de-shuttering and concreting of side walls, slab then finishing etc. taking several weeks, gets reduced by use of precast element transported and placed to a few days.

ii. Flexibility of range: can accommodate almost any size requirement: multi-cell sections of different shapes.

iii. Ease and rapidity of installation: Can be laid as single or in multiple cells.

iv. The length of the culvert can be increased by adjoining the units with one another.

v. Eliminates need of transport and erection of shuttering and staging on site which leads to reduction in cost and time.

vi. Being a product made in controlled environment, it exhibits high quality and uniformity.

vii. Aesthetically pleasing: Pre-cast concrete box culverts can also include spandrel and wing wall panels with a multitude of architectural finishes.

viii. In case the design incorporates overfills, there would be no need for approach slabs. This not only gives a smooth ride but also reduces maintenance.

ix. Reduced weather dependency leading to timely completion of the projects.

x. Superior strength and durability: Strength of pre-cast concrete gradually increases over time.

1.5 The type of precast concrete box section shall be appropriately selected. The dimensions of the box section and number of boxes are decided based on the hydraulic design as per IRC:SP:13. The box section shall be designed considering super imposed dead load, earth cushion, live load including dynamic impact, tractive and braking forces and earth pressure as per IRC:6-2017. “Good for Construction” drawings shall be prepared accordingly. For longer lengths, multiple segments shall be joined together at site by appropriate method.

2 SCOPE

2.1 These guidelines cover the requirements related to Precast Concrete Segmental Box Culverts. These guidelines deal with the construction methodologies for single-cell (or) multi-cell precast reinforced concrete box sections cast monolithically (or) partly and proposed for use in the construction of culverts and for the conveyance of storm water, or plain water.

These are also used for passage of traffic including usage as road (or) as parking on top of these precast reinforced concrete segmental box culverts.

2.2 The reinforced concrete shall be composed of cementitious materials as per IRC:112, IS:456, mineral aggregates as per IS:383, chemical admixture as per IS:9103 and water as per IRC:112 all latest editions. For concrete used for precasting of segments, the provisions of IRC:112 shall apply. For use of Precast Concrete Segmental Box Culvert as a hydraulic structure, the relevant provisions of IRC:SP:13 shall be applicable. Other elements like stone apron, wing walls, face wall, toe wall etc. shall also be designed as per IRC:SP:13.

3 SPECIFICATIONS

3.1 Many national and international specifications are being practiced and some of them are listed out in the Bibliography.

3.2 The precast concrete box culvert shall be strong, durable and manufactured in a controlled environment to ensure accuracy of dimensions and quality of the product. Precast production eliminates traditional on-site construction problems caused by substandard materials, uncertified craftsmanship, improper curing and bad weather, honeycombing in concrete, untimely and improper finish of the components.

3.3 The concrete mix properties and cover for precast segmental box section (placed over a compacted base) shall be selected depending on the severity of exposure condition as specified in IRC:112 and is given in **Table 1** or depending upon the concentrations of SO_3 ions in soil, subsoil or groundwater appropriate protective measures comprising selection of type of cement, mix proportions and protective coatings in severe cases as given in **Table 2**, whichever is stringent.

Table 1 Durability Recommendations for Service Life of at least 100 Years (Concrete with 20 mm aggregate)

Exposure Condition	Maximum Water/ Cement Ratio	Minimum Cement Content kg/m^3	Minimum Grade of Concrete	Minimum Cover (mm)
Moderate	0.45	340	M25	40
Severe	0.45	360	M30	45
Very Severe	0.40	380	M40	50
Extreme	0.35	400	M45	75

Notes:

(1) All four recommendations given in the **Table 1** for a particular exposure condition shall be satisfied.

(2) Minimum cover shown in **Table 1** can be reduced by 5 mm in case of factory made precast

concrete elements, high performance concrete, use of stainless steel or controlled permeability form work. In case more than one of the above measures are adopted the reduction should not exceed 10 mm.

(3) For elements below ground level, minimum cover shall be 75 mm.

(4) For design life of 50 years or less, the minimum cover can be reduced by 5 mm.

Table 2 Requirements for Concrete Exposed to Sulphate Attack

Class	Concentration of Sulphates as SO_3			Type of Cement	Minimum Cement Content	Maximum Water Cement Ratio	Minimum Grade of Concrete
	In Soils		In Ground				
	Total SO_3 %	SO_3 in 2:1 water: soil extract, g/l					
1	Traces	<1.0	<0.3	OPC PPC or PSC	280	0.5	M25
2	0.2 to 0.5	1.0 to 1.9	0.3 to 1.2	OPC PPC or SRPC	330 310	0.5	M25
3	0.5 to 1.0	1.9 to 3.1	1.2 to 2.5	SRPC PPC or PSC	330 350	0.5 0.45	M25 M30
4	1.0 to 2.0	3.1 to 5.0	2.5 to 5.0	SRPC	370	0.45	M35
5	>2.0	>5.0	>5.0	SRPC With protective coating	400	0.40	M40

Notes:

Type of Cements: OPC: Ordinary Portland Cement Grade 43 conforming to IS:8112
OPC: Ordinary Portland Cement Grade 53v conforing to IS:12269
PPC: Portland Pozzolona Cement conforming to IS:1489 (Part 1)
PSC: Portland Slag Cement conforing to IS:455
SRPC: Suphate Resisting Portland Cement conforming to IS:12330

3.4 Precast Concrete Segmental Box Culverts may be used in construction applications such as conveying storm water, storm drainage, utility conduit, underpasses, service tunnels, outfalls and the provision of access.

3.5 When ordering box culverts to casting yard or a separate manufacturing unit, specifications to be followed shall be given in writing and shall include:

- Specifications for the PCBC

- Name and location of the project
- Box size, laying length and the bury depth
- Design live load
- Type of joint of two units
- List of fittings
- Material test requirements
- Joint material and quantity

3.6 Other Requirements

3.6.1 *Site Inspection*

For Precast Concrete segmental Box culvert to work as Cross Drainage (CD) works, provisions of IRC:SP:13 shall be followed. For other types of structures the provisions shall be as per site specific requirements.

3.6.2 *Designs: Design Discharge, Linear Waterway, Normal Scour Depth, Maximum Scour Depth*

i. Hydraulic Design: For box culverts as Cross-Drainage (CD) structure, hydraulic design shall be as per IRC:SP:13.

ii. For box culverts as non-hydraulic structures, the dimensions of the structure shall be decided on the basis of site/project requirements.

3.6.3 *Clearances*

For Precast Concrete Box Culverts as CD works, clearances shall be as per IRC:SP:13. For concrete box sections as other structures, the vertical clearances shall be as per IRC:54.

3.6.4 *Bed Protection*

For box culverts as CD works, reference may be made to IRC:SP:13. For other structures, the precast box shall be placed on plain cement concrete (PCC) of M15 bed of adequate thickness so as to contain the bearing pressure within safe / allowable bearing capacity of the soil below the structure. However, the PCC bed thickness shall not be less than 100 mm.

3.7 Structural Design

Structural design of precast concrete segmental box shall be as per IRC:112. Designs shall depend on project requirements and applications. The precast concrete segments shall also be designed for handling and erection stresses based on the method of construction or site conditions. Box culverts can be designed to any standard or custom size and strength, including capability for with standing any loads. Additional features can include toe walls, headwalls, wing walls, and water tight joints where required and shall be designed as per the provisions of IRC:SP:13. The precast concrete segmental box culvert shall be designed for

the required forces. The dimensions of top slab, bottom slab and web shall be finalized on the basis of designs and project requirements.

3.8 Foundation

Box culverts are most suitable, where safe bearing capacity of soil is less than 10t/m^2. Where there are purely clayey strata, the top 900 mm below box should have granular material, like, sandy murum or stone dust. Where there is murum and mixed soil having Φ more than 15°, there is no need of providing sandy layer. Foundation requirement shall be as per the design, loading and site conditions. Segmental Precast Concrete Box cell can also be placed on the prepared concrete bed of required strength.

3.9 The techniques for handling precast units should aim for successful fabrication, delivery and installation without causing structural damage, detrimental cracking, architectural impairment or permanent distortion. A schematic sketch of a typical Box Cell is given in **Fig. 1.** Different uses of a Precast Concrete Box Culvert are shown in **Figs. 2, 3** and **4**.

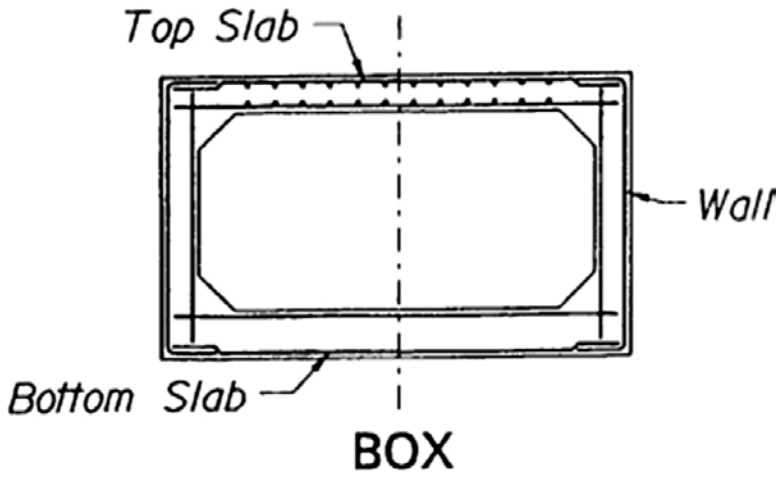

Fig. 1 Typical PCBC with Reinforcement and Haunches at Corners

Fig. 2 Cattle passing through Box Culvert

Fig. 3 Storm Water passing through Box Culvert

Fig. 4 Box Culvert as Underpass

3.10 The aggregates shall be sized, proportioned and mixed with such proportions of cementitious materials and water as will produce a thoroughly–mixed concrete of such quality that the box will conform to design requirements. All concrete shall have a water – cementitious material ratio not exceeding 0.45 by weight.

3.11 The box sections shall be cured for a sufficient length of time so that the concrete will develop a specified compressive strength in 28 days or less. The concrete box shall be cured by steam curing or water curing or membrane curing as specified in IRC:112.

The base, sub-base and sub-grade shall also be as per the intended usage of box culvert, traffic over it and invert level.

3.12 Precast Concrete Box Segments may be of different sizes and shapes. **Figs. 5, 6 and 7** shows various shapes of segments commonly used in practice.

Fig. 5 Elements of Precast Concrete Segmental Square Box Culvert

Fig. 6 Elements of Precast Concrete Segmental Rectangular Box Culvert

Fig. 7 Elements of Precast Concrete Segmental 'C' Section Box Culvert

3.13 Culverts shall be subject to loading as per design. The lifting system for precast concrete box culverts shall be simple, based on available resources, consistent with the design and without compromising quality **(Figs. 8 and 9)**.

Fig. 8

Fig. 9

Figs. 8 & 9 Lifting System of Elements of Precast Concrete Segmental Culvert

4 CONSTRUCTION METHODOLOGY

4.1 Types of Manufacturing Methods

There are two main methods of casting of PCBC. These are

i) Dry cast (Machine Made)
ii) Wet Cast

4.2 Dry Cast Method

In this method precast segments are cast using mechanized equipment. Form vibrators consolidate zero-slump concrete between core and jacket. Hole formers can be incorporated, or sometimes coring is resorted to as may be needed. The Precast Concrete segment is immediately stripped and the form is reused. Segments are typically cured in a curing tank, or moisture curing is used.

4.3 Wet Cast Method

In this method, the precast concrete segments are typically cast on using an inner and outer form. Forms shall be cleaned of concrete build-up after each use.Block outs/hole formers can easily be incorporated before concreting. The segments are cast using conventional concrete or self-consolidating concrete. Concrete cover shall not be less than that given in **Table 1**. Precautions shall be taken to ensure that the reinforcement does not move significantly during the casting operations. The segments are cured in the form.

IS:15916:2010 gives various accepted methods of manufacture of precast units. These have been broadly classified as:

a) The 'Stand Method' where the moulds remain stationary at places, when the various processes involved are carried out in a cyclic order at the same place, and

b) The 'Flow Method' where the precast unit under consideration is in movement according to the various processes involved in the work which are carried out in an assembly-line method.

Any method which is suitable to the project and site requirements shall be adopted.

4.4 Curing methods

Moist/wet curing, steam curing or Membrane curing shall be adopted as per IRC:112

4.5 Identification and Marking

All precast units shall bear an indelible identification, location and orientation marks as and where necessary. The date of manufacture shall also be marked on the segments. The identification markings on the drawings shall be shown in a table on the setting schedule together with the length, type, size of the unit and the sizes and arrangement of all reinforcement for easy identification of the segment.

4.6 Dimensions of the precast segmental box unit shall conform to the design requirements. The transportation/shifting of the pre-cast elements shall be carried out only after achievement of minimum strength of 20 MPa or 0.7 times the compressive strength of concrete. The strength of concrete shall be tested as per IS:516.

4.7 The delivery and off loading of precast concrete box culverts segments should be well planned. A suitable hard access that can be used safely by standard delivery vehicles and a suitable crane of adequate capacity shall be provided in the casting yard. The pre-cast concrete segments shall be properly cured to ensure achievement of appropriate strength.

4.8 Handling

Products shall be stored, handled shipped and unloaded in a manner to minimize damage. The handling process encompasses the demoulding of the precast units, their loading and transportation to storage areas, offloading and storage, transfer to site and site erection. To avoid excessive stresses and possible damage, all precast units should be handled in the manner as envisaged in their design by means of approved devices, identified in the production and erection drawings.

4.9 Lifting Equipment, Accessories, Storage, Transportation and Installation

Lifting holes or inserts shall be consistent with industry standards. Lifting shall be accomplished with methods or devices intended for this purpose Lifting equipment such as mobile crane, gantry crane, forklift etc. must be carefully selected to ensure that lifting of

precast units is carried out within the rated capacity of the equipment. The support for the lifting equipment must be checked to ensure that adequate supporting capacity is provided. Lifting accessories may comprise combinations of lifting beams or frames, slings or cables, hooks or shackles. The selection of each of these components should be predetermined to take account of the forces exerted on them due to various aspects of the lifting operations. A person suitably qualified in accordance with the relevant regulations must regularly inspect all lifting equipment prior to and after use. Results of such inspections must be properly recorded and be available for subsequent inspection. The location of lifting points should be clearly indicated on the drawings. Lifting methods may differ from different manufacturers and the same shall be agreed upon. Verticality or otherwise of the lifting ropes shall be as per the design requirements. During operation of lifting and unloading the precast concrete box culvert segment shall be protected from damage particularly the joining surfaces. Also, due care shall be taken for safety of the crew during this operation.

4.9.1 *Factory/Casting Yard and Site Storage*

Storage areas must be large enough so that the precast units can be stored safely, with adequate room for lifting equipment and transporting vehicles to manoeuvre. The ground of the storage area must be hard, level, clean and well drained to permit organised storage. Precast segments can be damaged by incorrect stacking and storage. Where the locations of support points for a precast unit are critical, the locations for the supports should be noted on the shop drawings.

Supports must be arranged to avoid twisting or distorting of the precast segments and must be adequate to transfer the weight of the stacked units to the ground without excessive settlement.

The stored and stacked units should be protected to prevent accidental damage and discolouration and the support material should be non-staining. Lifting points should also be well protected and kept accessible while the units are in storage. Precast segments must be stored safely with adequate supports such that it would not endanger any workers moving in the vicinity.

4.9.2 *Transportation*

Commonly precasting yards are at a distance from the project site where in these segments are to be used. Hence, it is necessary to transport them from casting yard to the construction site.

Transportation requirements will need to be met and permits, where applicable, obtained. Transportation must comply with the appropriate regulations. The precast units should have gained sufficient strength before being loaded for transportation.

4.9.3 *Loading and Storage on Transporters*

Precast units must be loaded carefully on to delivery vehicles to prevent damage. To protect the edges throughout their journey, proper devices should be used to support, secure and wedge the precast units. The units should be adequately secured and supported to prevent them from overturning, shifting or being damaged during transportation. Adequate non-

staining cushioning should be provided between the unit and any securing chains, cables or ropes to prevent localised damage.

Precautions should also be taken to ensure that no undesirable stresses will be transmitted to the precast unit due to any flexing of truck or trailer. Typical transportation vehicle is shown in **Figs. 10, 11** and **12.**

Fig. 10 Transportation of Sections of Box Culvert

Fig. 11 Transportation of Sections of Box Culvert

Fig 12 Transportation of Sections of Box Culvert

4.9.4 *Erection Preparation*

Consideration should be given to the following items to ensure safe and efficient installation of the precast elements in accordance with the design intent. For designing erection of precast concrete segments, provisions of Sub clause 11.10 of IS:15916:2010 shall apply.

Propping and temporary support details

If the sequence of erection is critical to the structural stability of the structure, or for access to connections at certain locations, it should be noted on the drawings. The erection drawings, which should include all relevant information, should be prepared prior to the commencement of any erection during Erection Safety.

Safety during the handling and erection of precast concrete elements is of paramount importance and compliance with the relevant current regulations is required.

All equipment used for the handling and erection of a precast element must be maintained to a high standard, load tested as necessary, and be suited to the intended use. Consideration should also be given to the site environment particularly with regard to built up areas and implications this may have on erection safety.

Erection sequence

Precast segments should be erected in accordance with a pre-planned sequence as detailed in the erection drawings. This sequence of erection should be such that the multiple handling of elements is minimised. A trial erection operation should be considered to identify any unforeseen erection difficulties.

4.9.5 *Missing or Damaged Lifting Inserts*

If missing, faulty or incorrectly located lifting inserts are identified, the designer should be contacted immediately to assess the problem and decide on an alternative lifting system. It should be verified, where permanent fixings or connections are temporarily used during construction, that the fixings are suitable for the temporary use and their long-term performance will not be compromised.

Fig. 13 Lifting and Placing of Box Segment

Erection tolerances

Generally, the precast unit should be erected in accordance with the stipulated tolerances, used in the design and specifications. **Fig.13** shows some lifting and placing of Box Segments

4.9.6 *Bedding Details*

Bedding details for box segments shall be as designed and specified. Proper support for a box culvert consists of specified bedding material having uniform flat surface as low or high points could create stress concentrations in the box after installation. The box segment, once installed, will not normally settle; it cannot be forced down to grade. Coarse bedding materials are not beneficial due to their irregular shape and sharp angles; instead medium to fine granular material should be used if concrete bedding is not used. A bedding thickness shall not be less than 100 mm. The width of the bedding material should equal the width of the box (span plus twice the wall thickness) and the length of the bedding material should equal the length of the box. In the event that the levelling course consists of layers with the upper layer being clean, uncompacted sand, that layer shall be a maximum thickness of 50 mm to prevent non-uniform settlement from personnel and equipment during the installation process. If rock strata or boulders are encountered under the box section, the same shall be removed and replaced with additional levelling course material. A concrete slab is not considered as an appropriate leveling course.

The box will tend to pull some bedding material toward the connection as it is aligned with the previous box segment. Excess bedding material trapped in the joint will prevent a proper alignment and connection and hence should be prevented. Therefore, at the connection end, a small trench should be dug. This allows for the bedding material to fall into the trench instead of the joint when the box is pulled into place. All bedding material characteristics should correspond to code and designer's plans for the specific project. Correct installation requires that the box culvert be installed on properly graded bedding. Any discrepancies in the installation of the culvert regarding bedding or grade should be addressed with the designer for remedial action. Bedding below box is shown in **Fig. 14**.

Fig. 14 Bedding Below Precast Concrete Segmental Box Cell

4.9.7 *Box Alignment during Installation*

It is critical that the first box segment should be installed correctly as it will determine the line and grade of the following boxes/segments. If these are not correct, future connections may be affected. The trench/bed shall be checked for line and gradient.

4.9.8 *Box Placement*

A box culvert line shall be usually laid from downstream end and a suitable joint sealing arrangement should be made. Placement of boxes should start at the outlet end of the line of box sections. The bell end should point upstream and the spigot or tongue should point downstream. Unless otherwise approved by the owner, loads from construction equipment transferred to a box section before, during, or after fill placement, either directly or through the fill, should not be greater than the loads assumed in the design. Using excavating machinery for the purpose of pushing boxes into place should be avoided, since this could cause cracking, requiring on-site repairing. Also, dropping or dragging the section over gravel or rock shall be avoided. A proper foundation for construction equipment should be available on site in order to ensure that no damage is caused to the levelling course and the sidewalls of the excavation area. PCBC shall be placed properly on the constructed base. The base shall be firm to avoid settlement of the units after loading. Bedding shall be properly designed. Improper bedding could prevent the tongue of the box from being properly inserted into the groove. It is very important that time be spent to ensure the box culvert bedding preparation is done correctly. Placement of Box Segment is shown in **Fig. 15**

Fig. 15 Placing of Section of Box Culvert

4.9.9 *Joints Sealing*

Many methods for jointing and sealing are available. The joints and sealing of units shall be as per the design or project requirements. The design of joints shall be made in the light of their assessment with respect to feasibility, practicability, serviceability considerations as per IS:15916:2010.

4.9.10 Normal joint is socket and spigot joint and same is generally used in culvert construction. Jointing is important in reducing the migration of soil fines and water between box sections and their surroundings. Depending on the use of the box culvert, various materials and methods may be used for sealing the joints. Box culverts specified for a soil-tight joint can be sealed between the joint with a bituminous mastic sealant. Either liquid butyl (bulk mastic) or non-shrink grout can be added to the outside top slab and applied down the sidewall 300 mm as well as applied to the inside bottom slab and inside sidewalls; or butyl sealant 25 mm thick and placed on the inside bottom and halfway up the sides of the bell end (approximately 13 mm from edge) and placed on the outside top and halfway down the sides of the spigot end (approximately 13 mm) from edge can be used to seal a soil tight joint. In cold weather it may be necessary to heat the butyl sealant with a hot water bath, bottle gas torch, or both. Placing this joint material in a sunny location, just prior to use, will allow heat absorption and make it more workable. Different grades of joint material are available for different temperatures.

Another joint commonly used is an extruded sealant which is placed between the joints. The extruded sealant can be applied in the same manner as the bituminous sealant, applied to the bell and spigot end of the sections being joined. In some areas, rubber gasket box joints may be available. Pre-made foam gaskets can also be used to seal joints. However these forms of sealant will have to be manually attached to the bottom of the spigot end of the box to prevent sagging. If the seal is insufficient then an added layer of adhesive joint wrap (butyl rubber laminated to polyethylene vapour retarder) can be used on the outside of the box to prevent infiltration. The external sealing band can also be non-woven geo-textile and should be placed on the sides and top of the box after installation. In certain situations, all four sides can be wrapped. In this case, the geo-textile material can be slipped under the box before it is set, then the sides and top can be sealed after the box is in place.

4.9.11 Backfilling should commence as soon as possible after the Precast Concrete Segmental box culverts have been placed by filling the trench evenly on both sides with a drainage layer of min 600 mm thickness and rest by using approved materials in layers not exceeding 200 mm. Backfill should be placed in uniform layers along the sides of the boxes and over the top of the box sections wherever required. The backfill material should not contain debris, organic matter, or large stones with a diameter greater than 1/2 the thickness of the compacted layers being placed. When vibratory compactors are used to compact the backfill material, care should be taken to avoid damage to the Box cell. In sections in cutting where space is a constraint, the back filling shall be done with granular material like coarse sand/gavel. Lift holes shall be properly sealed and plugged.

4.9.12 Construction machinery shall not be used over the box culvert without proper protection. Care must be taken since site traffic and construction equipment over shallow fill depths can impose loadings greater than those for which the finished box culvert has been designed. If construction equipment is going to travel over installed box sections, a temporary compacted backfill should be placed to a minimum of 1 m over the top of the box section unless the box has been specifically designed for the anticipated construction loads. The loads applied to the box section should not exceed those specified by the designer. In

an embankment installation, the minimum amount of backfill should extend one box section span or 1 m, whichever is larger, in each direction to prevent lateral displacement.

4.9.13 Box cell structures are to be provided with curtain walls and apron and these must be completed before floods. The best practice is to lay foundations of curtain wall and apron first and then lay the box. Apron pitching, toe walls etc shall be designed as per provisions of IRC:SP:13.

4.9.14 Made up of separate segments that are assembled in the field to make the final structure, segmental box sections are being used in building culverts for underground conveyance of storm water. In addition, culverts can also function as pedestrian tunnels as well as wildlife passage areas under heavily travelled highways.

4.9.15 Equipment used- Equipment used for precast concrete segments shall satisfy the requirements stipulated in IS:15916:2010

5 QUALITY MANAGEMENT

Quality Control

Fabrication precast segmental box culverts is simple and is generally done in the fabrication yard or casting unit. It is necessary to have quality control system in place for all elements, material and ingredients used in fabrication. Reference may be made to “Guidelines on Quality Systems for Road Bridges”, IRC:SP:47-1998. The specifications shall be in accordance with “Specifications for Road and Bridge Works” of Ministry of Road Transport and Highways published by the Indian Roads Congress.

5.1 Factory

For a mass scale production, the factory for the casting of units must ensure that the precast units are manufactured under a Quality Management System certified under ISO 9000 covering the following items:

- quality control tests of materials;
- calibration of laboratory equipment for quality control tests; and
- production process and control of equipment at the casting yard.

The factory and contractor shall be responsible for maintaining the quality of the manufacturing process for the precast units. The authorised person/registered structural engineer must satisfy himself that the precast concrete units have been constructed in accordance with the approved drawings and specifications. This may be achieved by providing full time construction supervision by their representative. If more stringent control on quality is considered necessary, the authorized person/structural engineer may step up the supervisory and testing requirements at appropriate place to test check the quality of the material and finished product.

Rigorous quality control procedures must be maintained at the precasting factory/casting yard at all times to ensure that the precast segments are constructed in accordance with the designs and specifications.

Upon leaving the precasting factory/casting yard all precast segments or batch of segments must carry documentation certified by the factory/casting yard stating that the segments have been manufactured under a certified quality assurance scheme and in accordance with the prescribed specifications.

5.2 Testing Standards

Concrete

Sampling and testing of concrete should comply with the IS: 1159 and IS: 516 and as required by the contract documents. The testing is to be undertaken by equivalent approved accredited laboratory.

Reinforcement

Reinforcing steel shall be of HYSD steel as per Table 18.1 of IRC:112. For seismic zones III, IV and V, HYSD bars having minimum elongation of 14.5% and conforming to other requirements of IS:1786 shall be used.

According to IRC:112, the corrosion resistance of reinforcing steel can be improved by using (i) galvanised reinforcement with coating as per IS:12594-1988, (ii) Epoxy coated reinforcement conforming to IS:13620-1993 or by (iii) stainless steel reinforcement conforming to IS:6744:2001

Sampling and testing of reinforcement should comply with the IS code. All testing is to be undertaken by equivalent approved accredited laboratory and in accordance with IS code or contract specifications

5.3 Site

The receiving, lifting, storage and erection at the construction site should be undertaken in accordance with the site accredited quality assurance scheme. The following items should form part of the site checking for acceptance of the precast elements:

Structural integrity

Although quality control checks are carried out for the precast units at the factory, there is a possibility of damage during handling and transportation. As the precast units are received on site they should be visually inspected for any signs of structural defect. Acceptance of any structural defect should be assessed with regard to the causes and the overall structural integrity of the precast units.

Dimensional tolerance

Dimensional tolerances of the precast units as received on site should comply with those specified in the contract documents. Changes to the dimensions and shapes of units should

be identified and assessed with regard to the overall tolerance; and surface finish. Finished segment tolerances should not exceed the following:

Length of segment (not cumulative):	± 5 mm
Overall span length :	±10 mm
Web thickness, depths of top and bottom flanges, Width of top and bottom flanges, overall depth of segment, thickness of diaphragm:	± 5 mm
Grade of form edge and soffit:	± 1.0 mm/m

The surface finishes of precast units when received on site should be checked for compliance with the requirements of the contract documents.

6 PRECAUTIONS AND SAFETY MEASURES

(i) Precast concrete segmental box shall be designed duly considering the loads, forces, handling, lifting, transport arrangement on site etc.

(ii) The lifting of the precast segment from the casting yard shall not commence unless the strength of the concrete achieved is checked and confirmed as per design.

(iii) Lifting arrangement, ropes, anchors for segment shall be designed for weight of segment, possible jerks, possible overloading etc.

(iv) During lifting and erection of the precast segment, workmen shall keep away at safe distance from the hanging segment to avoid any accident.

(v) Care shall be taken while handling or placing the precast segment to protect the edges, corners, shear keys etc.

(vi) Pulling of precast segments on the bed shall be avoided.

(vii) Uniform curing of the entire precast segment in the casting yard shall be ensured.

(viii) Design and preparation of the bed supporting the Precast Segment shall be done well in advance duly considering loads, forces to be sustained and bearing capacity of the strata below.

(ix) Construction machinery shall not be permitted on the top of the segment unless requisite earth cushion of 1.0 m is proved and loads are considered in the designs.

(x) Precast concrete segment shall be carefully inspected and checked for any cracks, spalling etc after casting as well as on placement on site.

7 MAINTENANCE

Precast box culvert requires little maintenance. However, routine pre and post-monsoon inspections need to be carried out to check the condition of bedding, apron and other silt deposition, scour, etc. Large box sections can be entered and examined. Timely action needs

to be taken to rectify/repair the defects noticed. Some of the typical defects and remedial actions are as given below:

- Debris shall be removed.
- Excessive cracks or large cracks noticed shall be repaired.
- Joints are properly sealed.
- The Invert shall be smooth and free of sags or high points.
- Lift holes are properly filled.
- Hook-ups, diversions and connections are properly made.
- Catch basins and inlets are properly connected.
- Manhole frames and covers are properly installed.
- Surface restoration and all other items pertinent to the construction are properly completed.

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(The Official amendments to this document would be published by the IRC in its periodical, 'Indian Highways' which shall be considered as effective and as part of the Code/Guidelines/Manual, etc. from the date specified therein)