भारतीय मानक

अधिप्लव मार्ग पोतघाट और शिखर के संरचना डिजाइन के मापदण्ड

Indian Standard

STRUCTURAL DESIGN OF SPILLWAY PIER AND CREST — CRITERIA

UDC 627·83·066

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

December 1992

Price Group 3

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by Spillways Including Energy Dissipaters Sectional Committee had been approved by the River Valley Division Council.

Spillway piers are erected over the crest profile and are provided to divide the spillway into number of bays so as to control the flow over the spillway by installing gates between two piers. Piers are also used to support the bridge over the spillway for the movement of gantry crane and normal traffic.

This standard is prepared to guide the designers, for the structural design of spillway pier and crest, based on the practices being followed in this country.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final values, observed or calculated, expressing the results of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

STRUCTURAL DESIGN OF SPILLWAY PIER AND CREST — CRITERIA

1 SCOPE

This standard lays down criteria for structural design of spillway pier and crest.

2 REFERENCES

The following Indian Standards are necessary adjuncts to this standard:

IS No.	*Title*
456 : 1978	Code of practice for plain and reinforced concrete (*third revision*)
1893 : 1984	Criteria for earthquake resistant design of structures (*fourth revision*)
6512 : 1984	Criteria for design of solid gravity dams
12720 : 1992	Criteria for structural design of spillway training and divide walls (*first revision*)
SP 55 : 1993	Design aid for anchorages for spillway structures (*under print*)

3 SPILLWAY PIER

3.1 Forces

Various forces to be resisted by pier are given below:

i) Self weight of pier
ii) Weight of spillway bridge on the pier
iii) Uplift pressure on the piers
iv) Weight of hoisting equipment on the pier
v) Upward water pressure on gates
vi) Weight of gate to be resisted by pier
vii) Reaction due to live load on the bridge including impact
viii) Crane loads, if provided
ix) Transverse water pressure on the pier
x) Force due to braking effect of vehicles
xi) Frictional resistance at the bearing of the road bridge
xii) Pin reaction in transverse direction due to water pressure on radial gate with inclined arms
xiii) Wind load
xiv) Earthquake (including hydrodynamic forces)
xv) Longitudinal static water pressure on the pier
xvi) Force due to wa ter current

NOTE — Effect of wind and earthquake forces should not be considered simultaneously.

Out of the sixteen forces mentioned above forces at Sl No. (i), (ii), (iii), (ix), (xii) and (xiv) have significant effect on design of pier while others have insignificant effect. The effect of the forces other than these, on the design of pier may be accounted for on percentage basis.

3.2 Design Loading Condition

The pier should be designed for the most critical loading combination. When one of the spillway gate is open and the adjacent is closed, the transverse horizontal force on the pier will be maximum. Therefore, the forces should be calculated for this condition. Longitudinal horizontal forces would be maximum when both the gates adjacent to the pier are in closed position (however, this condition generally would not be critical).

3.3 Computation of Forces

3.3.1 *Self Weight of Pier*

This should be calculated based on the actual geometry of the pier.

3.3.2 *Weight of Spillway Bridge on the Pier*

This load is transferred to the pier through the bearings and should be calculated accordingly.

Vertical load '*P*' per unit length should be calculated by dividing the load as calculated above by the length of pier '*L*' (*see* Fig. 1). To account for the vertical loads due to other insignificant forces, the vertical load per unit length as calculated above should be increased by 10 percent, in case it is not otherwise possible to calculate.

3.3.3 *Transverse Water Pressure on the Pier*

Water pressure on the shaded portion as shown in Fig. 1 should be calculated which will act at 1/3 height above the imaginary horizontal line drawn through the crest of the spillway. The pressure from the gate open side may be ignored. However, in case it is required to consider the same, it should be based on model studies.

3.3.4 *Pin Reaction in Transverse Direction due to Water Pressure on Radial Gate with Inclined Arms*

This is calculated for the condition when one gate is closed and the adjacent gate is open. This horizontal component of load (P_T) in transverse direction at trunnion due to water pressure on the gate is given below:

$$P_T = \frac{wh^2}{4} L \tan \theta$$

where

w = unit weight of water
h = height of gate
L = width of gate
θ = angle of inclination of arm with the pier

3.3.5 *Uplift Pressure on the Pier*

For planes below spillway crest level, the uplift pressure may be calculated according to **4.4.4**.

For planes above spillway crest level, the uplift pressure may be calculated as given below:

a) *When the tail water level is below the spillway crest level* — Uplift pressure equal to the hydrostatic head over the plane under consideration may be taken to be acting uniformly over the full width of the pier up to a distance A (*see* Fig. 1) and reducing to zero at the intersection of the plane with the upper nappe profile.

b) *When the tail water level is above the spillway crest level* — Uplift pressure equal to the hydrostatic head over the plane under consideration may be taken to be acting uniformly over the full width of the pier up to a distance A (*see* Fig. 1) and reducing to the head corresponding to the tail water level at the downstream end of the pier.

Uplift pressure per unit length for zones 1 and 2 may be calculated by dividing the total uplift force in the zones under consideration by their respective lengths.

3.3.6 *Earthquake*

Earthquake forces (including hydrodynamic forces) should be calculated according to IS 1893 : 1984.

3.4 Design of Spillway Intermediate Pier

3.4.1 The entire pier should be divided into three zones (*see* Fig. 2).

Zone 1 — Bending moment per unit length M_1, is as given below:

$$M_1 = \frac{M_H}{A + B}$$

where, M_H is moment due to the transverse water pressure about the imaginary horizontal line drawn through the crest of the spillway, and A and B are shown in Fig. 2. To account for the moments due to other insignificant forces, the moment per unit length calculated above should be increased by 20 percent in case it is not otherwise possible to calculate.

Zone 2 — Bending moment per unit length M_2, is given below:

$$M_2 = M_T + 0{\cdot}35\, M_1$$

where

$$M_T = \frac{P_T \times OT}{L_1}$$

where, P_T is horizontal component of loads at the trunnion due to water pressure at the gate (as calculated in **3.3.4**). OT and L_1 are shown in Fig. 1.

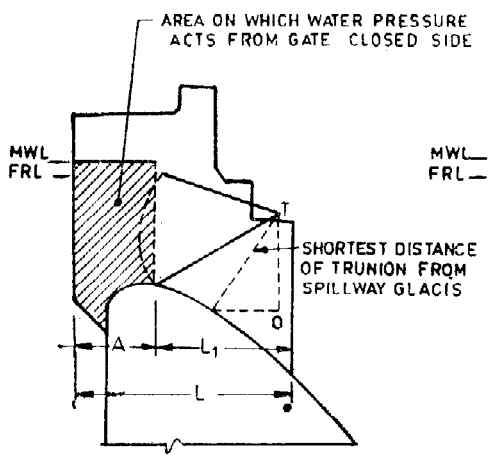


FIG. 1 WATER PRESSURE ACTING ON PIER

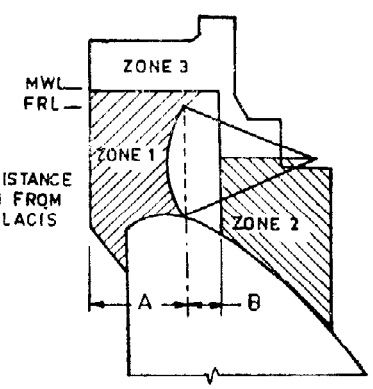


FIG. 2 ZONES OF PIER

Zone 3 — In this zone, there are no major forces, therefore minimum reinforcement of 25 mm diameter @ 30 cm c/c may be provided. However, minimum reinforcement should not be less than either 25 percent of the reinforcement in Zone 1 or 50 percent of the reinforcement in Zone 2. Maximum reinforcement obtained out of the above three conditions should be provided.

3.4.2 The pier reinforcement should be designed according to IS 456 : 1978, assuming the pier as an eccentric column for the vertical and horizontal loads as calculated in **3.3** and bending moments as calculated in **3.4.1**. The stress in steel and concrete should be ensured to be in permissible limits (*see* Fig. 3 for typical reinforcement detail). The permissible stress in steel reinforcement may be taken as 80 percent of the value specified in IS 456 : 1978.

3.4.2.1 *Anchorage*

The tensile stresses are also developed below the pier and, therefore, horizontal as well as vertical anchorages are required to be provided. The details of design of anchorage are given in IS 12720 : 1992 and design aid for anchorages in SP 55 : 1993.

3.5 Spillway End Pier

Under normal cases, a major portion of the end pier may be resting against the non-overflow dam adjacent to the spillway. Therefore, only a nominal reinforcement on the spillway face of the pier may be provided, which should not be less than 25 mm diameter @ 30 cm c/c. The reinforcement for the portion of the pier which is not resting against the non-overflow dam should be designed according to **3.3** and **3.4** (*see* Fig. 4 and 5 for typical reinforcement details).

3.6 As a guideline the following thickness/width of piers are recommended for different size of gates:

Sizes of Radial Gate (*Width* × *Height*)	*Thickness/Width of Pier*
12 m × 5 m	2·5 m
12 m × 6·5 m	2·75 m
12 m × 8·0 m	3·0 m
15 m × 12 m	3·50 m
9·15 m × 6·0 m	2·5 m
14·95 m × 10 65 m	3·50 m
15·55 m × 14 m	4·0 m
18·5 m × 16·75 m	4·75 m

4 SPILLWAY CREST

4.1 General

On account of the geometry of spillway crest profile, tensile stresses are developed in the crest because of the loads acting over it. Reinforcement needs to be provided to take care of these tensile stresses. The minimum thickness of structural concrete provided for spillway crest is 1·5 m, measured normally. However this has to be suitably increased to accommodate the anchorage below the piers.

4.2 Forces

Various forces to be resisted by the crest are as given below:

i) Self weight of pier and the spillway crest;

ii) Weight of water over the crest and tailwater, where applicable;

iii) Horizontal water pressure;

iv) Uplift pressure;

v) Earthquake forces (including hydrodynamic forces);

vi) Earth and silt pressure, if any;

vii) Ice pressure;

viii) Wave pressure; and

ix) Thermal loads.

4.3 Design Loading Condition

The spillway crest should be designed for the tensile stresses set up near the crest due to loads acting over it as mentioned in **4.2**. For the purpose of design the critical tensile stress should be calculated for the worst loading combination as given in **4.1** of IS 6512 : 1984. However, these should be calculated for the following three regions as shown in Fig. 6.

a) Considering block as a whole for section *XX* and below.

b) Region near the pier (At Section *YY*, that is above section *XX* as shown in Fig. 6).

c) Region away from the pier (At Section *YY*, that is above section *XX* as shown in Fig. 6).

4.4 Computation of Forces

4.4.1 *The Self Weights of the Pier and the Spillway Crest*

This should be calculated for the appropriate areas (*see* Fig. 6) depending upon the elevation at which stability is being checked.

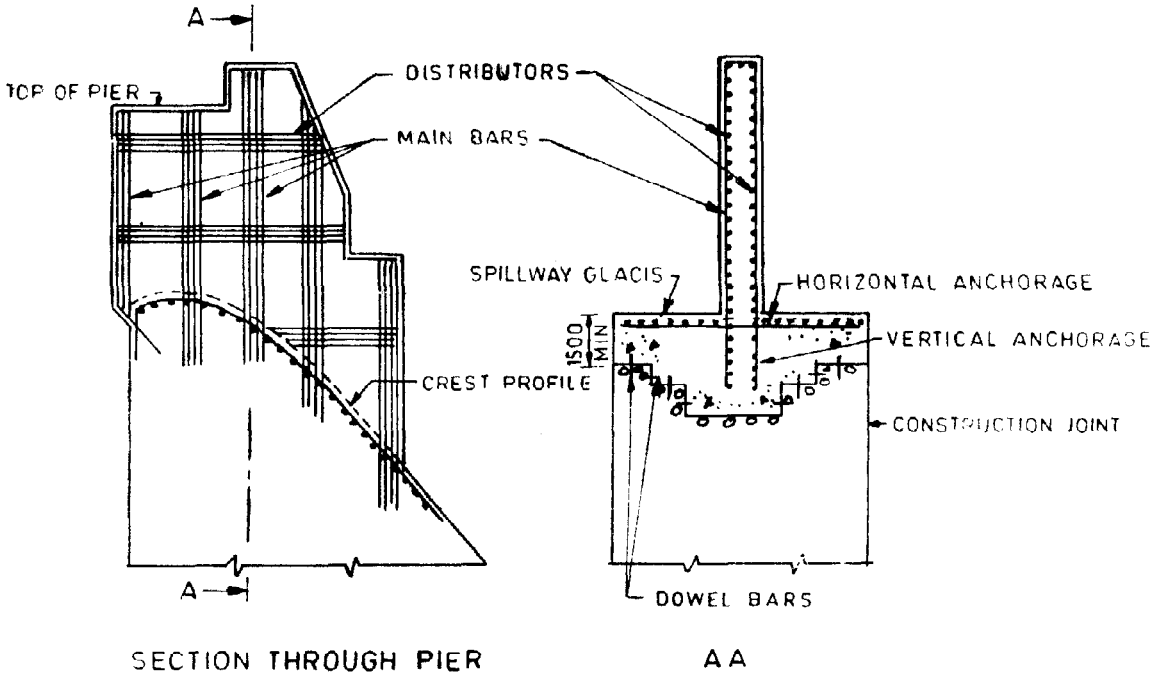


FIG. 3 REINFORCEMENT DETAILS FOR INTERMEDIATE PIER

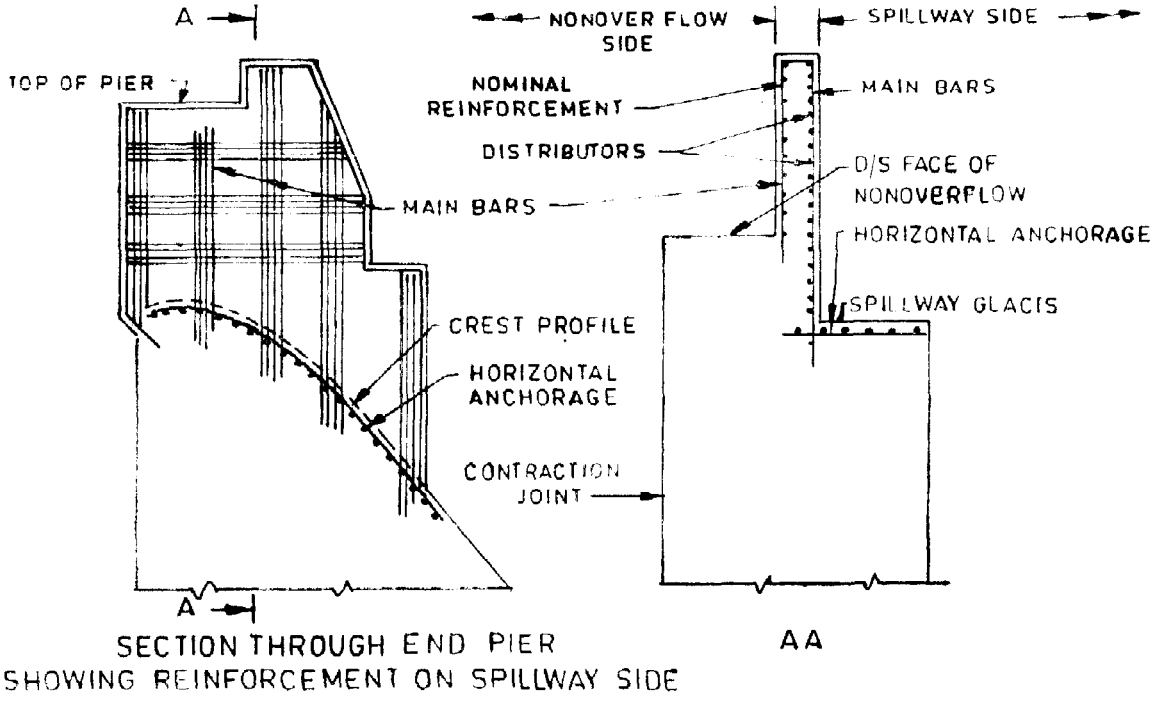


FIG. 4 TYPICAL REINFORCEMENT DETAILS FOR END PIERS

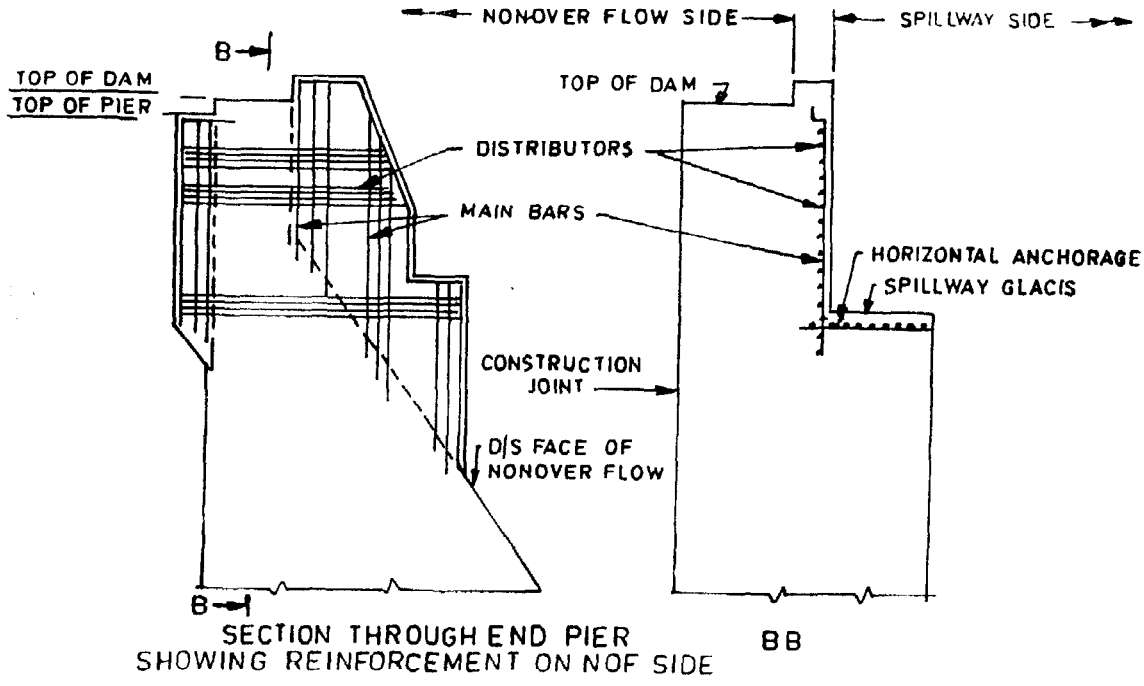
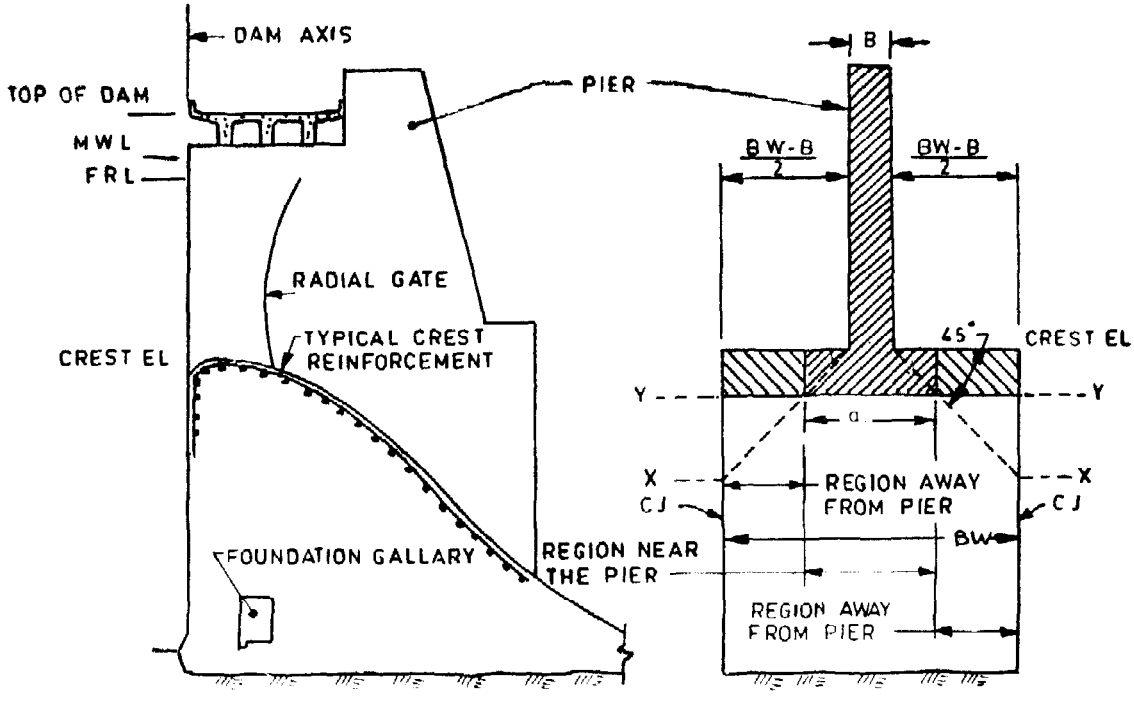


FIG. 5 TYPICAL REINFORCEMENT DETAILS FOR END PIERS TOWARDS NON-OVERFLOW SIDE



a is the width at section *Y Y* where stability is being checked.

FIG. 6 LOAD DISPERSION OF THE WEIGHT OF PIER ON SPILLWAY STRUCTURE

4.4.2 *Weight of the Water Over the Crest and Tailwater Level*

For spillway discharging condition, the weight of water over the crest should be ignored in the stability calculations for tail water levels below crest. If the design head is less than the head corresponding to MWL, negative pressures over the spillway crest which are likely to develop may be considered suitably either based on model studies or on earlier experience for similar conditions.

4.4.3 *Horizontal Water Pressure*

The horizontal water pressure acting above spillway crest elevation in respect of gated spillway over the gates should be taken to be transferred to the pier at an appropriate elevation depending on the type of gates used. For region away from the pier in respect of sections above *XX* (*see* Fig. 6) this force should not be considered.

4.4.4 *Uplift Pressure*

Uplift pressures should be considered to be acting over the spillway section only and not in the pier portion. For spillway discharging conditions and tail water levels, below the section at which stability is being checked, the effect of the sheet of water flowing over the spillway for uplift calculations may be ignored. For tailwater levels above the section considered, uplift at the downstream end and the weight of water above crest should be suitably considered (*see* Fig. 6).

4.4.5 The other forces mentioned in **4.2** (v) to (ix) should be computed as given in IS 6512 : 1984.

4.5 Reinforcement

4.5.1 Spillway crest reinforcement should be calculated in respect of the tensile stress as calculated in **4.3**. The crest reinforcement should be provided only if the tensile stresses exceed the allowable tensile stresses specified in **5.13.2.3** of IS 6512 : 1984.

4.5.2 The area of steel reinforcement should be calculated in accordance with IS 456 : 1978. The permissible tensile stress in steel reinforcement may be taken as 80 percent of the value specified in IS 456 : 1978.

4.5.3 The reinforcement should be provided up to an elevation below which tensile stresses are within permissible limits (*see* **4.5.1**). The development length below this elevation, however, be provided according to IS 456 : 1978.

4.5.4 Distribution reinforcement equal to not less than 20 % of the main reinforcement should be provided. However, it should not be less than 16 mm diameter @ 25 cm c/c.

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Doc : No RVD 10 (4592)

Amendments Issued Since Publication

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BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi 110002
Telephones : 331 01 31, 331 13 75

Telegrams : Manaksanstha
(Common to all offices)

Regional Offices :	Telephone
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002	331 01 31, 331 13 75
Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Maniktola, CALCUTTA 700054	37 84 99, 37 85 61, 37 86 26, 37 86 62
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Printed at New India Printing Press, Khurja, India