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# Discussion: Optimal design of curved bed trapezoidal canal sections

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Investigating the theoretical least-cost cross-sectional profile is a favourite academic exercise that has been explored in numerous papers. However, the practical implications of constructing curved section canals are less well documented but far more relevant. In practice the cost is rarely dependent on the theoretical minimum section, and the choice of geometry will depend on various factors, some of which are listed below.

(*a*) Limiting steepness of side slope for safety reasons, and ability of people and animals to get out of the canal.
(*b*) Stability of subsoil formation when cut to a slope. A varying slope, as in the case of curved profiles which flatten out with depth, is far more stable than a straight one.
(*c*) The specification of concrete, if used, and ease of placing concrete lining. Non-reinforced concrete of high strength is often stronger than reinforced concrete of medium strength.
(*d*) The need for longitudinal construction joints in concrete lining, which should not create discontinuity-induced internal stress.
(*e*) Ease of placing other lining material, such as less permeable compacted soil or artificial membranes.
(*f*) Whether maintenance equipment will be required to operate on the canal bed.
(*g*) The type of sediment expected to be deposited or required to be transported. Curved bed canals are not efficient at transporting coarse sediment, although deposited material will collect in the centre of the channel making it easier to remove during maintenance.
(*h*) Strength of rigid lining. A curved shell is inherently stronger than a section with planar sides and base. A very common cause of failure in trapezoidal lining is cracking at the base of the side slopes where a geometric discontinuity leads to intense stresses from soil pressure, soil movement or external loads.
(*i*) Placing concrete on a long constant slope in a trapezoidal section can be problematic as tension cracks develop owing to slippage of the wet concrete. This is not a problem in large parabolic sections, in which the slope is gradually reducing with depth below the bank top.

I have designed curved section canals of capacity from a few litres/s up to 500 $m^3$/s, a well-known example being the Pehur high-level canal in Pakistan which is a 30 cumec parabolic. This is a true parabolic with maximum side slopes restricted to 40° for reasons of safety and ease of escape. (In practice this is somewhat too steep, although escape steps were constructed at frequent intervals. For this size of canal a maximum slope of 30° would be better.) Being a level top canal, the depth and top side slope varies but the geometry of the templates used in forming earthworks and lining is constant and defined only by a simple relationship between a design top width and a design depth. Earthworks and dressing of the curved slopes were straightforward using 360° excavators from each bank. Concrete placement was simple and rapid using rotating striker tubes.

The much larger Merowe Left Bank Canal in Sudan was designed with lined side slopes restricted to 26°, for reasons of both safety and stability of the weak dispersive soils. It was also designed with a flat slab centre section to enable the operation of heavy machinery during maintenance closures. In this size of canal, with an overall width of 60 m or more, the trapezoidal section with curved lower side slopes was considered more appropriate for earthwork construction using heavy scrapers for bulk excavation, and 360° excavators for final slope dressing.

I have developed small precast parabolics up to 500 litres/s capacity in Indonesia, India and northern Pakistan, where they are now widespread and the farmers' choice for watercourses and minor canals, owing to their inherent strength and durability. In these small sizes the cost is dependent on the thinness of the section, which in turn can best be assured with a high-strength concrete, without reinforcement. For these canals the highest stresses always occur during transport and handling, and a suite of sections of tapering thickness were developed empirically with the benefit of regular feedback from actual field conditions.

Detailed accounts of curved profile lining design and construction can be found in Laycock (2007), Laycock *et al.* (2005) and from the website www.adrianlaycock.com.

## Authors' reply

The authors are fully in agreement with the contributor that the practical implications of constructing curved section canals are less well documented but far more relevant.

Continuous seepage from canals may cause serious water logging accompanied by salt accumulation, converting a once fertile land into a huge waste and spoil (Swamee *et al.*, 2000, 2001). One of the reasons for water logging of 12 000 ha of land in the Indira Gandhi Canal command in Rajasthan in India is the canal seepage (Swamee *et al.*, 2001, 2002). Lining is provided to check the seepage from a canal. But canal lining deteriorates with time and hence significant seepage losses continue to occur from a lined canal (Wachyan and Rushton, 1987). For the secondary line of defence, LDPE (low-density polyethylene) films along with conventional lining are used in India. However, such films become punctured at the base of the side slopes where a geometric discontinuity leads to intense stress concentration. In other countries HDPE (high-density polyethylene) films rather than LDPE films are extensively used owing to their superior quality (Deopura and Chahar, 2006, 2009). However, owing to their thickness, these sheets cannot be folded easily and are prone to stress cracking at the sharp edges of trapezoidal or triangular-shaped canals. Curved bed channels overcome these problems and are better suited. Novel sheet material (Deopura and Chahar, 2006, 2009) developed at IIT Delhi for lining also works well with curved channels. Therefore, curved bed sections along with other curvilinear sections (Chahar, 2006, 2007, 2009) should be adopted at large scale in canal projects as being implemented for parabolic sections by the discusser.

## REFERENCES


Chahar BR (2006) Analytical solution to seepage problem from a soil channel with a curvilinear bottom. *Water Resources Research* **42(1)**: **doi**: 10.1029/2005WR004140.

Chahar BR (2007) Optimal design of a special class of curvilinear bottomed channel section. *Journal of Hydraulic Engineering* ASCE **133(5)**: 571–576.

Chahar BR (2009) Seepage from a special class of a curved channel with drainage layer at shallow depth. *Water Resources Research* **45(9)**: **doi**: 10.1029/2009WR007899.

Chahar BR and Basu S (2009) Optimal design of curved bed trapezoidal canal sections. *Proceedings of the Institution of Civil Engineers, Water Management* **162(3)**: 233–240, **doi**: 10.1680/wama.2009.162.3.233.

Deopura BL and Chahar BR (2006) Geomembranes for water management. *Proceedings of IGS International Seminar on Geosynthetics in India: Present and Future*, New Delhi, pp. 92–102.

Deopura BL and Chahar BR (2009) Water seepage control through novel sheet materials. *Proceedings of 60th IEC Meeting and 5th Asian Regional Conference of ICID, New Delhi.*

Laycock A (2007) *Irrigation Systems – Design, Planning and Construction*. CABI, Cambridge, MA.

Laycock A, Swayne C and Marques JEJ (2005) Pehur high level canal, Pakistan. *Proceedings of the Institution of Civil Engineers, Water Management* **158**(3): 93–102.

Swamee PK, Mishra GC and Chahar BR (2000) Design of minimum seepage loss canal sections. *Journal of Irrigation and Drainage Engineering ASCE* **126(1)**: 28–32.

Swamee PK, Mishra GC and Chahar BR (2001) Design of minimum seepage loss canal sections with drainage layer at shallow depth. *Journal of Irrigation and Drainage Engineering ASCE* **127(5)**: 287–294.

Swamee PK, Mishra GC and Chahar BR (2002) Design of minimum water loss canal sections. *Journal of Hydaulic Research AIHR* **40(2)**: 215–220.

Wachyan E and Rushton KR (1987) Water losses from irrigation canals. *Journal of Hydrology* **92**(3–4): 275–288.


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