Sag Pipe (depressed sewers, or Inverted siphons)
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A sewer that drops below the hydraulic gradient to pass under an obstruction, such as a railroad cut, subway, highway, conduit, tunnel, valley or river, is often called a sag pipe. This pipe is drop sharply, then run horizontal under the obstruction, and finally rises to the desired elevation. It may be used in drainage system.

Fig.(1) Longitudinal section in a sag pipe

Sag pipe acts as a trap, the velocity of sewer flow should be greater than 0.9 m/s (3 ft/s) or more for domestic wastewater, and 1.25 to 1.5 m/s (4 to 5 ft/s) for stormwater, to prevent deposition of solids (Metcalf and Eddy, Inc. 1991).

Thus two or more siphons are needed with an inlet splitter box. In practice, minimum diameters for sag pipes are usually the same as for ordinary sewers: 150 or 200 mm (6 or 8 in) in sanitary sewers, and about 300 mm (12 in) in storm sewers (Metcalf and Eddy, Inc. 1991).

The determination of the pipe size for sag pipes is the same as for water and wastewater mains. The size depends upon the max. wastewater flow and the hydraulic gradient. Due to high velocities in sag pipes, several pipes in parallel are commonly used. For example, it may be that a small pipe may be designed large enough to carry the min. flow; a second pipe carries the difference between the min. and average flow (or max. dry-weather flow); and a third pipe carries peak flow above the average flow.

Sag pipes can be constructed of ductile iron, concrete, or PVC.
Fig. (2) Overall Diagram

Fig. (3) Plan view of inlet chamber (3 siphons)

Fig. (4) Section A-A (exploded scale)
Design Example:
Design a sag pipe system using the following given conditions:
1. Dia. of gravity sewer to be connected by sag pipe = 910 mm (36 in)
2. Slope of incoming sewer, $S = 0.0016$ m/m (ft/ft)
3. Min. flow velocity in sag pipe = 0.9 m/s (3 ft/s)
4. Length of sag pipe = 100 m (328 ft)
5. Max. sag pipe = 2.44 m (8 ft)
6. Design flows:
   Min. flow = 0.079 m$^3$/s (2.8 ft$^3$/s)
   Average flow = 0.303 m$^3$/s (10.7 ft$^3$/s) = max. dry-weather flow
   Full (max.) flow = capacity of gravity sanitary sewer
7. Design three sag pipes from the inlet chamber
   (1) to carry min. flow
   (2) to carry flows from min. to average
   (3) to carry all flows above the average flow
8. Available fall from invert to invert = 1.0 m (3.3 ft)
9. Available head loss at inlet = 125 mm (0.5 ft)
10. Available head loss for friction in sag pipe = 1.0 m (3.3 ft)
11. Available hydraulic grade line = 1 m/100 m = 0.01 m/m
12. $n = 0.015$ (ductile-iron pipe)

Note: The above information is required to design a sag pipe system.

Solution:
Step 1. Design the sag pipe
(a) Calculate velocity and flow of the 910 mm sewer for full flow

\[
R = \frac{d}{4} = \frac{910 \text{ mm}}{4} = 227.5 \text{ mm} = 0.2275 \text{ m}
\]
\[
V = \frac{(1/n)R^{2/3}}{S^{1/2}} = \frac{(1/0.015)(0.2275)^{2/3}(0.0016)^{1/2}}{0.994 \text{ m/s}} = 0.994 \text{ m/s}
\]

Flow $Q = AV = 3.14 (0.455 \text{ m})^2 (0.994 \text{ m/s}) = 0.646 \text{ m}^3/\text{s}$

(b) Determine the size of the small sag pipe to carry the min. flow ($d = \text{dia. of the pipe}$)
\[ Q = \pi \left( \frac{d}{2} \right)^2 (1/n) \left( \frac{d}{4} \right)^{2/3} S^{1/2} \]
\[ = (0.3115/n) \ d^{8/3} S^{1/2} \]
0.079 = (0.3115/0.015) \ d^{8/3} (0.01)^{1/2} \\
0.079 = 2.077 \ d^{8/3} \quad [*] \\
\frac{d^{8/3}}{d} = 0.038 \\
d = 0.293 \text{ m} \\
\approx 300 \text{ mm} \\
= 12 \text{ in} \\

Using a 12-in (304 mm) pipe will just carry the 0.079 m³/s flow Check velocity 

\[ V = (0.397/n) \ d^{2/3} S^{1/2} \quad [0.397 = 1/4^{2/3}] \]
\[ = (0.397/0.015) \ (0.304)^{2/3} (0.01)^{1/2} \]
\[ = 2.647 \ (0.304)^{2/3} \quad [**] \]
\[ = 1.20 \text{ m/s} \quad \text{verified, > 0.9 m/s) } \]

*Note:* A nomograph for the Manning equation can be used without calculation.

(c) Determine the size of the second sag pipe for maximum dry-weather flow above the minimum flow

\[ Q = (0.303 - 0.079) \text{ m}^3/\text{s} \]
\[ = 0.224 \text{ m}^3/\text{s} \]

From [*]

0.224 = 2.077 \ d^{8/3} \\
\frac{d^{8/3}}{d} = 0.1078 \\
d = 0.434 \text{ m} \\
= 17.1 \text{ in} \\

A standard 18-in (460 mm) pipe would be used.

Check velocity of 460mm pipe.
From [**]

\[ V = 2.647 (0.460)^{2/3} = 1.58 \text{ m/s} \quad > 0.9 \text{m/s} \quad \text{ok} \]

The capacity of the 460 mm pipe would be 

\[ Q = 2.077 (0.46)^{8/3} \]
\[ = 0.262 \text{ m}^3/\text{s} \]
(d) Determine the size of the third pipe to carry the peak flow, from steps (a) & (c). the third pipe must carry
\[ Q = (0.646 - 0.079 - 0.262) \text{ m}^3/\text{s} \]
\[ = 0.305 \text{ m}^3/\text{s} \]

The size \((d)\) required would be
\[ d^{8/3} = \frac{0.305}{2.077} \]
\[ d^{8/3} = 0.1468 \]
\[ d = 0.487 \text{ m} \]

The size of 500-mm (20-in) diameter standard is chosen. The capacity and velocity of a 500-mm pipe with 0.01 hydraulic slope is
\[ Q = 2.077 (0.50)^{8/3} \]
\[ = 0.327 \text{ m}^3/\text{s} \]
\[ V = 2.647 (0.50)^{2/3} \]
\[ = 1.67 \text{ m/s} \quad > 0.9 \text{ m/s ok} \]

(e) Calculate total capacity of the three pipes (300, 460, and 500 mm)
\[ Q = (0.079 + 0.262 + 0.327) \text{ m}^3/\text{s} \]
\[ = 0.668 \text{ m}^3/\text{s} \text{ (0.646 m}^3/\text{s is needed)} \]

**Step 2.** Design the inlet and outlet chambers
These sag pipes are connected from the inlet chamber & outlet chamber. Weirs (2m in length) are installed to divide the chamber into three portions.

Fig. (5) Detail of sag pipe
**Construction Notes:**

1. It is recommended that the design of long sag pipes include a blowoff structure at the low point of the alignment to allow for draining of the system. These can be designed for operation by pumping or gravity draining. Shorter sag pipes can usually be easily drained by pumping from either end of the structure.

2. Sag pipes pose a significant risk to human and animal safety. Specific features must be included in the design of these structures to help alleviate these risks.

3. Air vents, pressure-release valves, or air jumper pipes may be necessary to relieve air pressure in the sag pipe, especially under less-than-capacity flows. A hydraulic jump can occur in the pipe, causing blowback and significantly reducing the capacity of the siphon. The aforementioned appurtenances allow for the release of trapped air from the pipe.

Reference: