of nine counterforts, 13 to 37 feet thick, projecting 26 feet from the base. The dam was originally built vertical on the down-stream face, and stepped on the waterside. Its height above bed is 73.2 feet, extreme height 92.9 feet; top length 1804.6 feet; thickness at base 45.9 feet, at top 21.32 feet. It is founded on argillaceous rock, rather soft. The dam was built in 1830–38, on the Brenne River, for feeding the navigable canal of Bourgogne.

**The Chazilly Dam** was constructed after the general type of the Gros-Bois dam, and on the same profile. It is on the Sabine River, near the city of Chazilly, and is 1758.6 feet long, 73.8 feet high, 53 feet thick at base, 13.4 feet at crest.

**The Zola Dam**, designed by the father of the noted novelist, is one of the few dams depending solely upon their arched form for their stability. It is 119.7 feet high, 48.8 feet thick at base, 19 feet thick at top, and 205 feet long on the crest, which is surmounted by a parapet 4 feet high. The gorge has a width of but 23 feet at the base of the dam. The radius of the arch is 158 feet at the crown. The water-face has three steps or offsets from the vertical and the profile is quite erratic and irregular. It forms a reservoir for supplying the city of Aix with water, and was built about the year 1843. It is made of rubble masonry, founded on rock.

**The Furens Dam.**—Among many engineers this famous dam is recognized as a model of correct form, profile, and dimensions, whose outlines conform closely to what are accepted as certainly safe and well-balanced proportions throughout, even though the volume of material may be slightly excessive. It was built by the French Government in 1862 to 1866 for the purpose of controlling the floods of the Furens River and protecting the town of St. Etienne from inundations.

The dam is 183.7 feet in extreme height on the down-stream side, 170.6 feet in height on the up-stream side, and carrying a maximum depth of 164 feet of water. Its base thickness is 165.8 feet, and it is 16.4 feet thick at a depth of 21 feet below the top. The crest is 12.4 feet wide, and is used as a carriage-road; the top length is 326 feet. The dam was four years in building, construction being limited to six months each season, owing to the altitude and to the severity of the winter weather. Each year, while building, the water was allowed to flow over the top of the finished masonry, and when completed no leakage was visible further than a few damp spots on the lower side with full reservoir.

The dam contains 52,300 cubic yards of masonry, and cost $318,000, of which the city of St. Etienne paid $190,000 for the privilege of the storage for its domestic supply. The rock used was mica-schist. Notwithstanding its safe gravity profile the dam was curved up-stream, with a radius of 828 feet for architectural effect. The volume of water stored by this great dam, the highest in France, is comparatively insignificant,



being but 1297 acre-feet (422,625,000 gallons). M. Graeff, Chief Engineer of the Department of the Loire, and M. Delocre designed the dam, and M. Montgolfier was engineer in charge of construction.

**The Ternay Dam.**—Located on the river Ternay, in the province of Ardèche, southern France, this dam was erected in 1865 to 1868, for controlling floods and supplying the neighboring town of Annonay. It is constructed of granite rubble masonry, and is founded on bed-rock of granite. The proportion of mortar in the work was 40%. In plan it is curved with a radius of 1312 feet, while the profile is a gravity type, resembling that of the Furens dam. The extreme height is 119 feet, and bottom thickness 89.2 feet. The up-stream face is vertical for 58.5 feet, and battered below that point. The lower face is chiefly formed in a vertical curve of 147.6 feet radius, reaching from the water-level to within 30.5 feet of the bottom, the slope to the base being tangent to the curve. The center of the circular curve is 7.5 feet above the crown of the dam.

The dam was designed and built by M. Bouvier, Engineer des Ponts et Chaussées, under the general direction of J. B. Krantz, Chief Engineer. The profile of the dam, however, is considerably lighter than the type recommended by M. Krantz in his "Study on Reservoir Walls," which form resulted from his adherence to a limiting pressure of 6 kilograms per square centimeter (85 lbs. per square inch) upon any portion of the masonry, whereas the maximum pressures in the Ternay dam are estimated to be 9 kilos per square centimeter. M. Krantz comments, however, on the Ternay dam as follows: "The reservoir wall of Ternay, which was remarkably planned and built by M. Bouvier, has, in my opinion, scarcely a defect."

The capacity of the reservoir back of the dam is 686,766,000 gallons (2107 acre-feet). The total cost of the dam was $204,372.

**The Vingeanne Dam, France.**—This structure resembles the Ternay in height and general form, being 113.8 feet high, 18.1 feet thick at base, 11.5 feet on top. It is located near the town of Baissey, and was built in 1885.

**The Ban Dam, France.**—Next to the Furens dam in height the reservoir wall constructed in 1867 to 1870, near the city of St. Chamond, was built upon the same general principles, except that a greater maximum pressure was permitted upon the masonry, the computed extreme being 8.18 tons per square foot. Its extreme height is 157 feet, length 512 feet, base thickness 127 feet, top width 16.4 feet. The wall is battered or curved on both sides, there being no vertical faces. In plan it is curved convex up-stream. It is composed of rubble masonry founded on rock. It is used for the supply of the city of St. Chamond, and its cost was $190,000.

**The Verdon Dam, France.**—This structure is not of great height, being but 59 feet, but its construction presented great difficulties, owing to the volume of water carried by the Verdon river, and the narrow canyon in which it was placed. The low-water flow is 350 second-feet, while in floods the discharge reaches over 4200 second-feet. The dam had to be founded on rock, after excavating 20 feet through gravel and bowlders; and as the canyon is but 130 feet wide at the top of the dam and considerably less at the water-level, there was little room to do the work and take off the constant flow.

The dam is used for diverting water to a canal, supplying the city of Aix and other places in the vicinity. The dam proper is curved up-stream with a radius of 108.8 feet, resting on a rectangular base of concrete. The masonry consists of rubble with cut-stone facings. The general dimensions are:

| | |
|---|---|
| Length on top | 131.3 feet. |
| Thickness of base | 32.5 " |
| Thickness of crest | 14.2 " |
| Height above river-bed | 40.2 " |
| Height above foundations | 59.0 " |

The concrete foundation has a thickness of 48 feet. This is protected from the falling water by an embankment of large blocks of loose stone. The maximum depth of overflow was estimated at 16.4 feet.

**The Pas Du Riot Dam, France.**—Subsequent to the construction of the Furens dam, a second storage-reservoir for the further supply of the city of St. Etienne was built in 1872 to 1878 to the height of 113.2 feet, curved in plan, and similar in profile to its greater neighbor. The reservoir formed by it has a capacity of 343,380,000 gallons (1054 acre-feet). The cost of the dam was $256,000.

**The Cotatay Dam, France.**—In 1885 a dam was built on the Cotatay brook near the city of St. Etienne to supply the city of Chambon-Feugerolles. This also is of the Furens type, curved in plan, and has a maximum height of 144.3 feet, with maximum depth of water of 121.4 feet. It is curved on a radius of 1148 feet, and is 508 feet in length on top. It was built in 1900–04 on the Cotatay river by M. Reuss, Engineer of Bridges and Roads.

**The Pont Dam, France.**—This structure, of granite rubble, founded on rock, has a maximum length of 495 feet and an extreme height of 85 feet. It is curved in plan, with a radius of 1312.4 feet. The base thickness is 62 feet, and crest 16.4 feet. The water-face batters 4.2 feet in its total height.

On the lower face, from the top down for 62.3 feet, is a vertical curve, whose radius is 98.4 feet. The remaining height has a batter tangent to this curve. Nearly 20 feet of the base of the dam is below the river-bed. Seven counterforts or buttresses, 16 feet long, 3 feet thick, help sustain the dam. The dam was built in 1883 on the Armançon River, 2½ miles from the city of Semur.



**The Chartrain Dam, France.**—The profile of this modern structure, built in 1888–92, is one of the most graceful and scientific in design of all of the French dams of recent construction. It has a maximum height above lowest foundations of about 180 feet, and a base width on top of foundations of 135 feet, the foundations extending above and below the toes of the wall to a total width of 156 feet.

The dam is located on the river Tache, and was built to store water for the supply of the city of Roanne. The reservoir, however, is quite small for so high and costly a dam, covering but 54.36 acres in area and impounding 3647 acre-feet to a mean depth of 67 feet, or 41% of the maximum depth.

The cost of the dam was $420,000, or $115.10 per acre-foot of storage capacity.

**The Bousey Dam, France.**—The failure of this structure April 27, 1895, with the loss of one hundred and fifty lives and the destruction of much property, has particularly emphasized the value of several features of masonry dams which may be regarded as essential in the design of all such works:

1st. That they be founded on impermeable bed-rock, and the possibility of upward pressure from water passing through fissures be avoided.

2d. That they shall have a profile of such dimensions as to permit of no tension in the masonry.

3d. That the masonry shall be practically impervious to water.

4th. That it be curved in plan to avoid temperature cracks and movements as the result of expansion and contraction of the masonry.

The Bousey was lacking in all of these essential features, and its failure was not surprising in the light of all the facts that have been published regarding it.

It was built in 1878 to 1881, near Epinal, France, across the small stream of Avière to form a storage-reservoir of 1,875,000,000 gallons for supplying the summit level of the Eastern Canal, which here crosses the Vosges Mountains in connecting the rivers Moselle and Saône, this canal being a connecting link in interior navigation between the Mediterranean and the North Sea. The reservoir was fed by an aqueduct from the Moselle River. The reservoir covered an area of 247 acres. The general dimensions of the dam are as follows:

| | |
|---|---|
| Length on top | 1700 feet. |
| Height above river-bed | 49 " |
| Height above foundations | 72 " |
| Width on top | 13 " |
| Width 36 feet below water-level | 18 " |

The wall was vertical on the water-face from top to bottom.

The masonry was founded on red sandstone, which in places was fissured and quite permeable, with springs which gave trouble in constructing the foundations. The foundation was not excavated to solid, impermeable rock under the entire dam, but an attempt was made to remedy this deficiency by building what was called a "guard-wall," 6.5 feet thick on the upper side of the dam, extending down below the foundations through the imperfect rock for the purpose of cutting off leakage underneath. This was carried up to the river-bed and lapped against the main wall. The dam was completed in 1880, and the following year water was admitted. When it had reached about one-third the height, 33 feet below the top, enormous leakage, amounting it is said to 2 cubic feet per second, appeared on the lower side of the dam, partly due to two vertical fissures or expansion-cracks in the wall. March 14, 1884, when the water had risen to within 10.4 feet of the top, the pressure was sufficient to bulge the wall forward for 444 feet, forming a curve convex down-stream, the extreme movement being from 1 to 3 feet according to different authorities. Four additional fissures then appeared, and the leakage increased to about 8,000,000 gallons per day. These cracks opened in winter and closed in summer. The water was kept behind the dam and the following year allowed to rise to within 2 feet of the top, after which it was drawn off, when it was discovered that for 97 feet the dam had been shoved forward, separating from the guard-wall, and numerous cracks were found on the inner face. Extensive repairs were then undertaken. The joint between the main wall and the guard-wall was covered with masonry and surrounded by a bank of puddle, 10 feet thick, while a heavy, inclined buttress-wall was built at the lower toe, deep into the bed-rock, and toothed into the masonry of the dam to prevent the tendency to slide on its base. This abutment was nearly 20 feet in height, and its base was 84.3 feet below the top of the dam, making the total thickness of base 71.6 feet. Notwithstanding all this work the dam was fatally weak at a point near the river-bed level, where the line of resistance falls considerably outside the middle third, and the final break occurred at a point about 33 feet below the top, where the fracture was almost horizontal longitudinally, and 594 feet of the central part of the dam was overturned. The break was level transversely for about 12 feet and then dipped toward the outer face. The repairs finished in 1889 were presumed to have made the dam safe, and the break did not occur for six years afterwards, during which time the action of temperature-changes is presumed to have produced the weakness resulting in the final catastrophe. An interesting account of the failure of the dam was published in *Engineering News*, May 16 and 23, 1895. The lesson taught by it will be serviceable to engineers the world over.

**The Mouche Dam, France.**—The purpose of this structure, completed



in 1890, is similar to that of the Bousey dam—to form a storage-reservoir for feeding a navigable canal. It is located on the Mouche River, near the village of St. Ciergues, and forms a reservoir of 241.8 acres, having a mean depth of 29 feet and impounding 7010 acre-feet. The general dimensions are as follows:

| | | |
|---|---|---|
| Length on top | 1346 | feet. |
| Maximum height, lowest foundation to parapet | 114.5 | " |
| Height, base to water-line | 94.5 | " |
| Width of base | 66.7 | " |
| Width of top | 11.6 | " |

The up-stream face has a batter of 1 foot in 50, while the down-stream batter is nearly 1 to 1.

The dam is straight in plan and carries a roadway over the top, nearly 25 feet wide, supported by arches resting on abutment-piers that give the required extra width. There are forty of these arches, each with a span of 26.2 feet.

The masonry was found experimentally to weigh 134.2 lbs. per cubic foot, and the computations of the profile were made on that basis, preserving the lines of pressure, reservoir full and empty, well within the center third.

The excavations for foundation were required to be so deep to reach bed-rock that 56% of the masonry is laid below the surface, the maximum depth of excavation being about 40 feet. The water-face of the dam was given three coats of hot pitch, and subsequently whitewashed.

**Settons Dam, France.**—This structure was built originally with the view to improving navigation on the Yonne River, in 1855-58. It had an extreme length of 889 feet, a maximum height of 69 feet, and was 14 feet wide on the crest. In 1899 the dam was reinforced by the addition of a "guard wall" on the up-stream face for its entire height, the wall having a thickness of 17.3 feet, with a number of vertical wells constructed in the wall to intercept and drain off the leakage through the wall.

**Avignonet Dam, France.**—This dam is remarkable for the fact that it has been built to the height of 75.5 feet as an overfall weir in the river Drac, which in flood carries as much as 35,000 sec.-feet, without having been founded on bedrock. It was located in a narrow gorge whose sides rise nearly 1000 feet, and the stream being torrential in character the canyon had been filled to a great depth with boulders and gravel, the excavation in which to reach bedrock would have been exceedingly deep. Therefore the engineers decided to build it on the detritus of the canyon, merely sinking two cut-off trenches about 13 feet deep, 8 feet thick, and giving the dam a base of 78.4 feet, which is greater than its height.

The dam is curved in plan, on a radius of 656 feet, is 196.8 feet long on the crest, and is 15.6 feet thick on top, with a roll-way form on the down-stream slope. (See plate I.) The toe of the dam is extended down-stream by an apron of reinforced concrete. The entire dam is built of concrete, was completed in 1902, and is used for the development of power for the city of Grenoble, whose population in 1896 was 64,000.

**The Sioule Dam, France.**—This structure, erected in 1902-04, across the Sioule River, is utilized for water storage and power, the power-house being located immediately below the dam. It is curved in plan, with a radius of 984 feet, and is 393.7 feet long on the crest, has a maximum height of 98.4 feet, is 79 feet wide at base, and 16.4 feet wide on top. At each end of the dam an overflow weir is provided, extending parallel with the valley, and nearly at right angles with the direction of the dam.

**The Miodeix Dam, France.**—The storage of water and the development of power from the Miodeix river, for the city of Auvergne, was the purpose of the erection of this dam in 1903. The maximum height is 80 feet, the crest width 10 feet, and the base 69 feet, The up-stream batter is 9% and that of the down-stream face is 80%, with a vertical curve near the top, having a radius of 26.4 feet, above which it is vertical for 8.4 feet to the top.

**The Turdine Dam, France.**—A reservoir of 28,840,000 cubic feet capacity (661 acre-feet) was formed in 1902-04 for the water-supply of the city of Tarare (population in 1896, 14,500) by the erection of a masonry dam of triangular profile, having a height of 82 feet, a base width of 65 feet, and a crest width of 13 feet. The dam is curved in plan, with a total length of 394 feet on top. The up-stream batter from the base up for 15 meters is 8.33%, thence to the top 5%, while on the down-stream face the batter from foundation up to a height of 11.12 meters is 80%, thence by a vertical curve of 49.5 feet radius to within 5.4 feet of the top. The spillway level is but 2.3 feet below the crest of the dam. This dam is about 20 miles northwest from the city of Lyon, and about 35 miles north of St. Etienne, the location of the Furens dam.

**The Echapre Dam, France.**—One of the high modern dams of France was that erected in 1894-98 for the water-supply of the city of Firminy, Department of the Loire (population in 1891, 14,500). The maximum height above lowest foundations is 160 feet, the width at base 88.6 feet and on top 17 feet. It carries a maximum depth of water of 121.4 feet. It is curved in plan on a radius of 1148.2 feet, and is 541 feet long on the crest. A pleasing architectural effect is given to the down-stream face by a series of arches, with spans of 13 feet, which support the side of the roadway on top of the dam, which has been corbelled out over the arches to give the desired width of roadway and sidewalks. The arches rest on pilasters 4 feet wide. The arches have a total height of 33 feet. The up-stream face of the dam is vertical for 99 feet from the top down, while the lower face batters about 76%. The spillway of the dam at one side is 101.7 feet long. The dam was designed and built by M. G. Reuss, Ingénieuer des Ponts et Chaussées. The reservoir for so high a dam is comparatively small in capacity, containing but 33,535,000 cubic feet, or 770 acre-feet. The dam is but a few miles west of the Furens dam.



**The Ondenon Dam, France.**—Quite similar in design to the Echapre and Cotatay dams is the structure erected in 1900-04 by the same engineer, to store water for the supply of the town of La Ricamarie. It is 123 feet in height, carrying a maximum depth of 107 feet of water. It is also curved in plan, with a radius of 984 feet, is 420 feet long and 15.4 feet wide on top, with a base width of 94 feet. It also carries a roadway on top, supported by corbeling out the normal width on 10 foot arches resting on pilasters. The reservoir capacity is extremely small, being but 14,120,000 cubic feet (324 acre-feet) and is indicative of the scarcity of good reservoir sites in that region.

**The Cher Dam, France.**—One of the highest of the modern French dams is now under construction to create a storage reservoir for the supply of the City of Montlucon, in Central France (population in 1896, 31,600) and for power development, the capacity being about 20,000 acre-feet. The height will reach 158 feet; crest width 15.4 feet; base thickness 141 feet. It is to be curved in plan, with a radius of 656 feet. The Cher River, on which the dam is located, is one of the tributaries of the Loire.

### Dams in Italy.

**The Lagolungo Dam, Italy.**—This structure was built in 1883 to a height of 131 feet, and 20 years later, in 1903, it was decided to increase its height by ten feet. The dam is immediately above the Gorzente dam, near Genoa, and creates a reservoir for the supply of that city, with a capacity of 130,000,000 cubic feet, or 2950 acre-feet. As originally constructed it was given a thickness of 140 feet at the base, 16.4 feet at the crest, with a parapet 8.4 feet higher than the top of the dam. The addition to the height was made by replacing the old parapet by a new one, 14 feet high, 16 feet wide at the base, 8.2 feet wide on top—in other words, the dam was simply added to on the top from the original crest width of 16.4 feet to the new width of 8.2 feet, while the spillway, which was 72 feet long, was built up 10 feet higher with masonry. A second spillway, 59 feet long, was added. Both weirs have flash boards on their crest to give additional reservoir capacity, which now amounts to 156,700,000 cubic feet (3600 acre-feet) with possible increase of 5.5% by the flashboards.

The dam is provided with cast-iron outlet pipes at four different levels, by means of which the water may either be turned into the aqueduct leading to the city or into the next reservoir below, formed by the Gorzente dam.

**The Gorzente Dam, Italy.**—The city of Genoa derives a water-supply from a reservoir formed by a masonry dam, built in 1882, on the Gorzente River. The reservoir capacity is 748,800,000 gallons (2298 acre-feet), covering 64 acres. The dam has a maximum height of 121.4 feet, and is 492 feet long on top, 23 feet thick at top, 99.6 feet thick at base. The masonry is a rubble composed of serpentine rock and mortar of Casale lime and serpentine sand.

**Cagliari Dam, Italy.**—This structure is located on the island of Sardinia, 13 miles from the city of Cagliari, on the Corrungius River. It was built in 1866, and is 70.5 feet high, 52.5 feet thick at base, 16.4 feet at top, and 344.5 feet long on top. It is built of rubble masonry composed of granite and a hydraulic lime mortar, mixed with clean, well-washed, granitic sand.

### French Dams in Algeria.

**The Habra Dam, Algiers.**—The French Government has built, or encouraged the construction by private parties of, a number of notable storage-reservoirs for irrigation in Algiers, of which the largest was that formed on the Habra River, by a masonry dam, whose disastrous failure has made it well known among the engineering profession, and added to the many lessons which such failures carry with them. The dam was begun in November, 1865, completed in May, 1873, and after eight years of service was ruptured in December, 1881, causing the loss of 209 lives and the destruction of several villages.

The main dam was straight in plan and 1066 feet long on top, flanked by an overflow wall, 410 feet long, making an angle of 35° with the direction of the dam, the top of which was 5.2 feet below the crest of the dam proper.

The maximum height of the dam was 117 feet from foundation to the water-line, above which a parapet extended 8 feet higher. The dam was 14 feet thick at top, 88.4 at base, battered on both sides and of ample dimensions to withstand the water-pressure, provided the masonry had been properly constructed and of first-class material. When completed and first filled the dam leaked like a gigantic filter, but the leakage practically ceased in course of time.

The reservoir formed by the dam had a capacity of thirty million cubic meters, or 24,330 acre-feet. The watershed of the Habra River is very extensive, covering 3859 square miles above the dam, from which the



annual discharge, however, was only about $3\frac{1}{2}$ times the capacity of the reservoir, owing to the slight rainfall of that region. The summer flow was about 18 second-feet, and the normal winter flow was about 100 second-feet, while extreme floods reached 25,000 second-feet in volume. The flood which caused the rupture of the dam came from a rainfall of $6\frac{1}{2}$ inches in one short storm, during which the run-off in one night was computed at 3,500,000,000 cubic feet, or more than three times the reservoir capacity. This resulted in a general overflow of the crest of the wall, as the spillway was of insufficient capacity, and produced such excessive pressure upon the outer face of the masonry as to exceed its normal strength. Over 300 feet of the wall was torn out to the very foundation.

In a paper on the subject written the following year by the eminent Italian engineer, G. Crugnola, he attributes the failure to inferiority in the quality of the masonry. The sand was not of good quality, and in the center of the dam a red earth, containing 22 to 24 per cent of clay, was used instead of sand. Furthermore, the mortar was made of hydraulic lime burned from calcareous rock found on the banks of the river, which, though hydraulic, was not very good. The inference drawn by M. Crugnola is that the hydraulic lime contained a quantity of quicklime, which expanded in time, causing porosity if not actual cavities in the interior of the masonry. The stone, as well as the mortar, was extremely porous, consisting chiefly of calcareous Tertiary grit, which was of variable hardness, some having a decided schistose structure.

One must conclude from all the facts that had the spillway been sufficient in capacity to avoid the submersion of the dam, and had the face of the wall been made absolutely water-tight by such precautionary measures as were employed on the Remscheid dam, the failure would not have occurred. The curvature of a wall of the great length of the Habra would doubtless have avoided temperature cracks, which, as has been pointed out by Prof. Forchheimer (page 122), may have been a leading source of weakness. The failure occurred during the coldest weather, when such cracks appear in masonry walls.

**The Hamiz Dam, Algiers.**—Next in importance to the Habra dam, and somewhat higher, is the Hamiz dam, erected in 1885 on the Hamiz River. This wall is also straight in plan, but only 532 feet in length on top, 131 feet long at base. The extreme height above foundation is 134.5 feet, and above river-bed 91.2 feet, and at top 16.4 feet. Both faces are curved in outline.

The dam impounds 10,500 acre-feet of water, gathered from a shed of 54 square miles.

**The Gran Cheurfas Dam, Algiers.**—This structure is quite similar in dimensions to the Hamiz dam, and was built in 1882–84, on the Mekerra River, 9 miles from St. Dionigi. Its foundation extends 32.8 feet below the river-bed, and has a thickness of 134.5 feet at base and 78.7 feet at top. On this foundation the dam proper rests, with an offset of 3¼ feet on each side, making its thickness at bottom 72 feet, while at top the wall is 13 feet thick. Both faces are curved in parabolic form, presenting a graceful profile. The maximum pressures on the masonry are 6.1 tons per square foot.

The dam failed in part when first filled, and a breach of 130 feet was made in the wall, but it was immediately repaired. The failure occurred in winter. The dam is straight in plan.

The reservoir capacity behind the dam is about 13,000 acre-feet.

**The Tlelat Dam, Algiers.**—This masonry wall is 69 feet high, 325 feet long, 40 feet thick at bottom, 13 feet thick at top, and impounds 445 acre-feet, derived from a water-shed of 51 square miles. The dam was erected in 1869 on the Tlelat River to supply the town of Sante Barbe, 7½ miles below, and also for irrigation. The wall is vertical on the water-face, while the lower side has a vertical curve, the center of radius being 11.8 feet above the top of the dam.

**The Djidionia Dam, Algiers,** is 83.7 feet in extreme height, of which 28 feet is foundation below the river-bed level. The face is vertical, and the dam is straight in plan. The foundation is broader on top than the bottom of the dam, and will permit of an increased height in the structure by adding to the lower side from the foundation up. This has been decided upon, and 26 feet additional in height will be built. The reservoir will then have a capacity of about 4000 acre-feet. The dam was built in 1873–75, on the Djidionia River, to supply the towns of St. Aimé and Amadema with water. The masonry of this dam is slightly in tension on the water-face when the reservoir is filled, amounting to about 15 lbs. per square inch, but no injurious effect upon the masonry is apparent from this small tensile strain.

## Dams in India.

**The Tansa Dam, India.***—This great dam, forming a reservoir for the supply of Bombay, was begun in 1886, and completed in April, 1891. The work was done by contract and cost $988,000. It is straight in plan, the alignment consisting of two tangents, and it has a total length of 8800 feet, the maximum height being 118 feet. For a length of 1650 feet the dam is depressed 3 feet, to serve as a waste-weir. The thickness of the masonry at the base is 96.5 feet, and the entire section is made of sufficient

* See Proceedings Institution of Civil Engineers, vol. cxv. Paper by W. J. C. Clerke, M.I.C.E., on "The Tansa Works for the Water-supply of Bombay"; also, "Irrigation in India," by Herbert M. Wilson, 12th Annual Report U. S. Geological Survey.