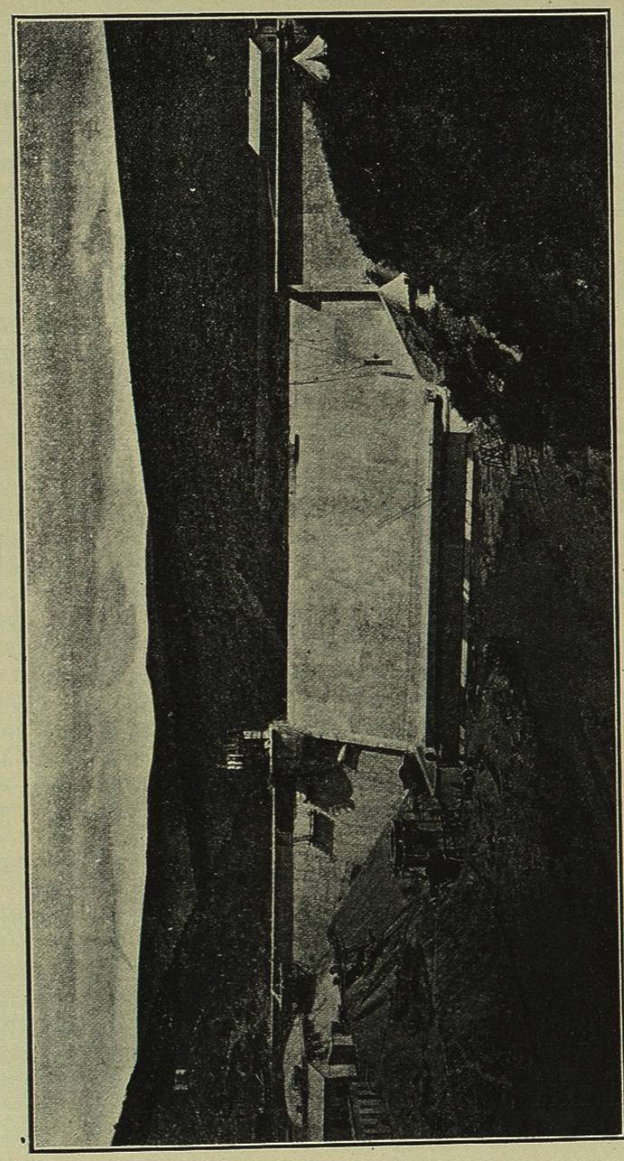


Fig. 268.—Sand River Dam, Cape of Good Hope, South Africa.

tion being 340 feet long and the length over all 585 feet. The radius at the crest of the arch was 275 feet, decreasing to 206 feet 75 feet below, to meet the lines of the gravity dam on tangent. After stripping a depth of 12 to 14 feet, a base of concrete 40 feet wide, 15 feet thick, was laid, in which railway rails were embedded in two layers, one longitudinally near bedrock and the other transversely about two feet below the top. On this foundation the masonry work of uncoursed rubble was laid with a base width of 36.5 feet, decreasing to 33 feet at a height of 20 feet, and to 7 feet at the crest. The total volume of masonry in the dam was estimated at 30,000 cubic yards. The materials were handled by a Lidgerwood cableway, suspended across the gorge. The rock used was a hard blue quartzite, quarried half a mile away. The water was to be pumped from the dam to a service reservoir $1\frac{3}{4}$ miles distant, at an elevation of 575 feet above the dam.

The reservoir covered an area of 104 acres, and had a capacity of about 3900 acre-feet. The works were planned by Wm. Ham. Hall, M. Am. Soc. C. E., as consulting engineer, with Mr. J. B. Rogers as resident engineer.

Construction was well advanced at the time of the breaking out of the Boer war, which caused a suspension of operations.

Dams in Germany.

The Remscheid Dam, Germany (Fig. 269).—This structure is one of the best existing types of reservoir walls, as they are designed and built by modern German engineers, and possesses more than ordinary interest. It is 82 feet high, 49.2 feet thick at base, 13.1 feet thick at crown, and is curved in plan, with a radius of 410 feet. The total contents of the dam are 22,886 cubic yards, and its cost is given at $91,154, an average of $3.98 per cubic yard. The reservoir formed by it has a capacity of 35,310,500 cubic feet, of 811 acre-feet, while its average cost was $112.45 per acre-foot of storage capacity.

The dam is built across the Eschbach valley, and is designed to supply the city of Remscheid, and manufacturers in the valley below. It was begun in May, 1889, and water turned on November, 1892. It is composed of rubble masonry, the stone, a hard slate, being laid in trass mortar. Trass is a rock of volcanic origin, from which hydraulic lime is made resembling pozzuolana, used so extensively in Italy. The mortar consists of one part lime, one and one-half parts trass, and one part sand, and was preferred by the engineer to Portland cement, because it sets more slowly and tests showed it to be superior in point of elasticity. The dam has shown no settlement, no cracks, and no leaks. The courses of masonry were laid so as to be as nearly perpendicular as possible to the varying direction of the resultant pressures at all points. The water-face of the dam was

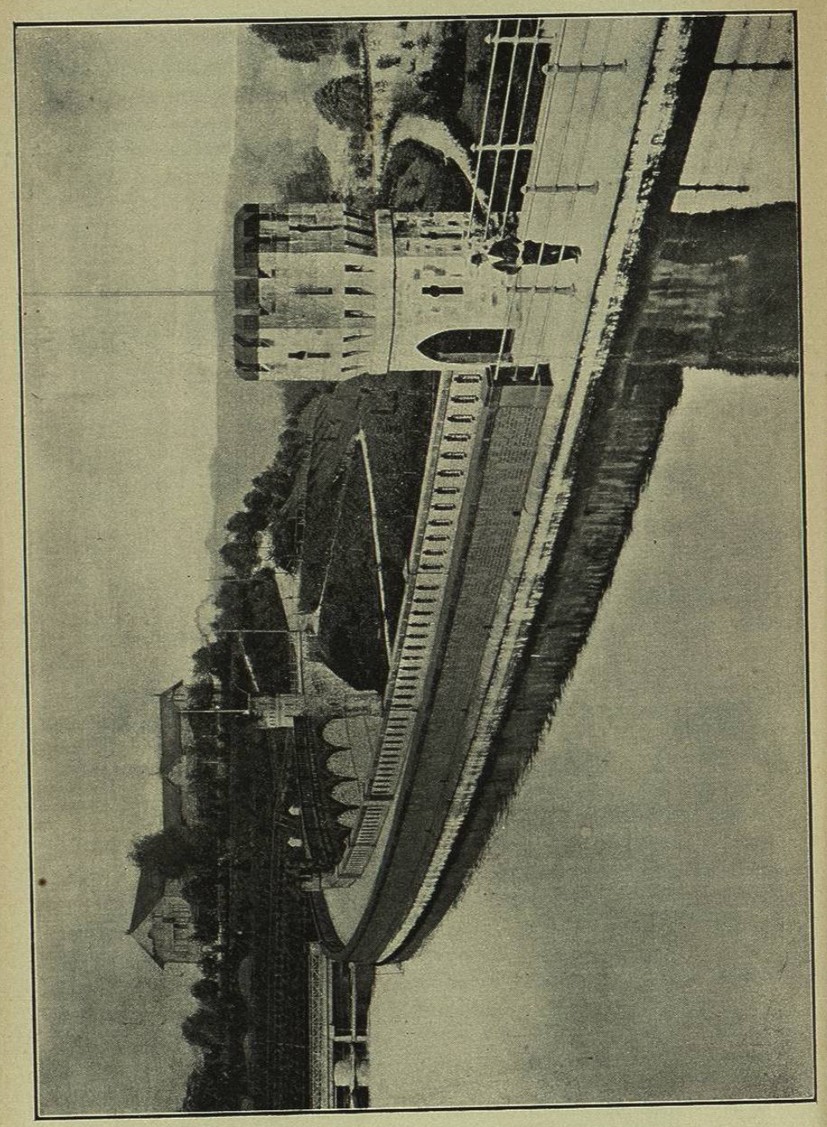


FIG. 269.—THE REMSCHEID DAM, GERMANY.

plastered with cement mortar, over which two coats of asphalt were placed, the asphalt extending 20 inches over the bed-rock. Then a brick wall, 1½ to 2½ bricks thick, was carried up outside, tight against the asphalt.

The dam was designed and built by Prof. O. Intze, and described in a paper published in the *Journal of the Society of German Engineers*, from which the facts above given are gleaned.

The Einsiedel Dam, Germany.—This dam was completed in 1894, and forms a reservoir for supplying the city of Chemnitz. It is composed of rubble masonry, the total volume of which was 31,600 cubic yards. Its maximum height above foundation is 92 feet, of which 65 feet is above the natural surface. The length over top is 590 feet, top thickness 13 feet, base 65.5 feet. It is curved to a radius of 1310 feet. The storage capacity of the reservoir is 95,000,000 gallons (291 acre-feet).

The Urft Dam, Germany.—The highest dam in Europe is that built in 1901 to 1904 across the river Urft, near the city of Aachen, Germany (population in 1895, 110,500), the seat of the great Polytechnic School, one of whose Professors, Otto Intze, designed the structure, which is but an hour's journey from the famous Gileppe dam, in Brussels. The dam is curved in plan, on a radius of 656 feet, and has a crest length of 741 feet. Its maximum height is 190.3 feet. Its thickness at base is 165.7 feet, and at top 18 feet, at a height of 4.9 feet above the spillway level. The base is exactly equal to the maximum depth of water. On the up-stream face of the dam an earth embankment is built to within 77 feet of the top, having slope of 2 on 1, paved with rock. The body of the dam is built of slate masonry laid in courses inclined against the lines of pressure, after the plan of the Remscheid dam, while on the up-stream face is laid a separate wall of traprock masonry, 3 feet thick, the stones of which are stepped on the battered portion of the face. Previous to laying this face wall the masonry was covered with a plaster coat of cement, one inch thick, and a coat of asphaltum, to insure water-tightness. As an additional precaution for the same purpose, the earth embankment was built as described. To provide for the drainage of any water that might penetrate the body of the masonry in spite of these extraordinary measures, two rows of 2½ inch clay pipes were placed vertically in the heart of the dam, from top to bottom, the pipes being 8 feet apart in each row. The pipes of each row are connected to a 6-inch header pipe that leads to the drainage tunnels built through the dam near the center at the lowest level. In each drainage tunnel, which extends through the earth embankment to the reservoir, a 23-inch steel washout pipe is laid.

The main outlet of the reservoir is a tunnel, 9200 feet long, about a mile north of the dam. Water carried through this tunnel supplies power

under a head of 360 feet, from which 10,000 H. P. is generated in 8 units and transmitted to neighboring manufacturing towns. (See Fig. 270.)

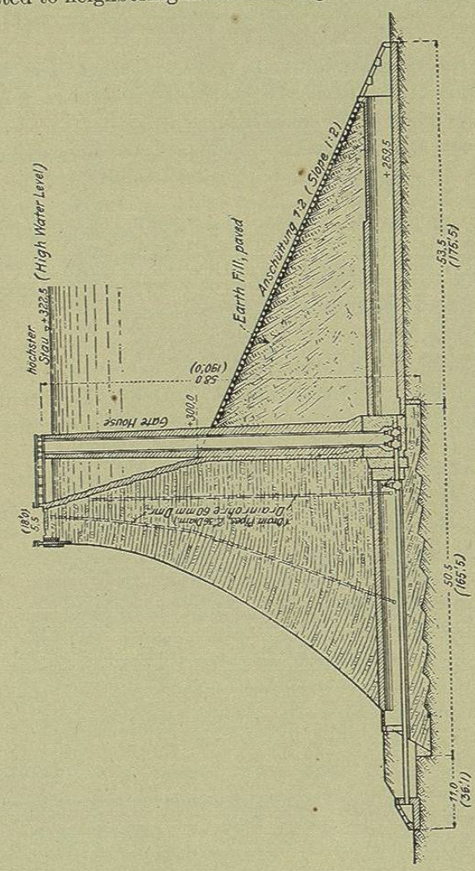
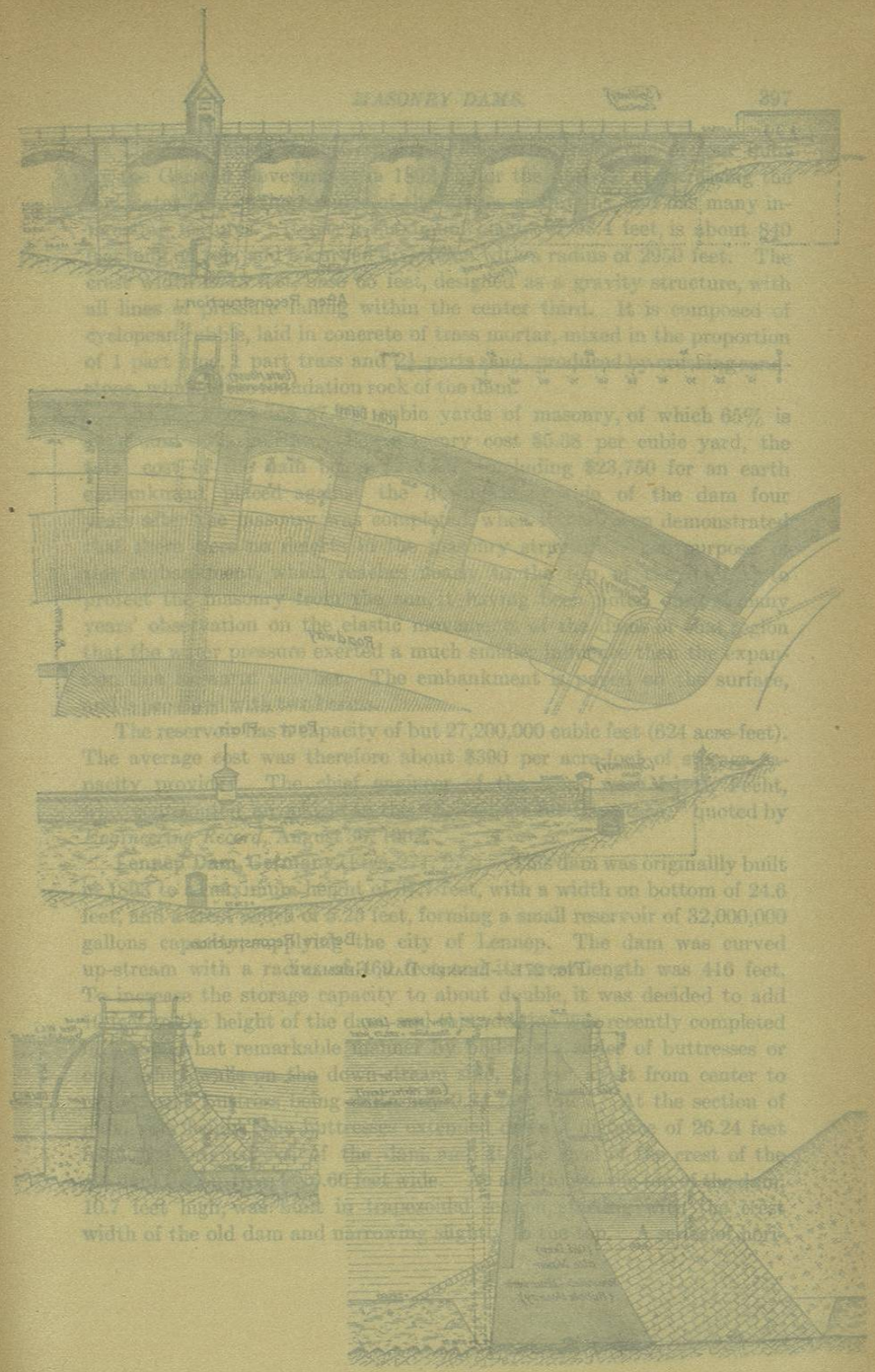


FIG. 270.—URFT RIVER DAM, GERMANY.

The Solingen Dam, Germany.—The water supply of the city of Solingen (population in 1895, 40,800) is in part derived from a reservoir formed by a stone masonry dam, arched in plan, on a radius of 492 feet, having a crest length of 585 feet. Its length at base is 125 feet; the thickness at top is 14.7 feet, and at the foundation level the masonry is 120 feet thick, while the maximum height is 141 feet. The location of this dam is but a short distance from Remscheid.



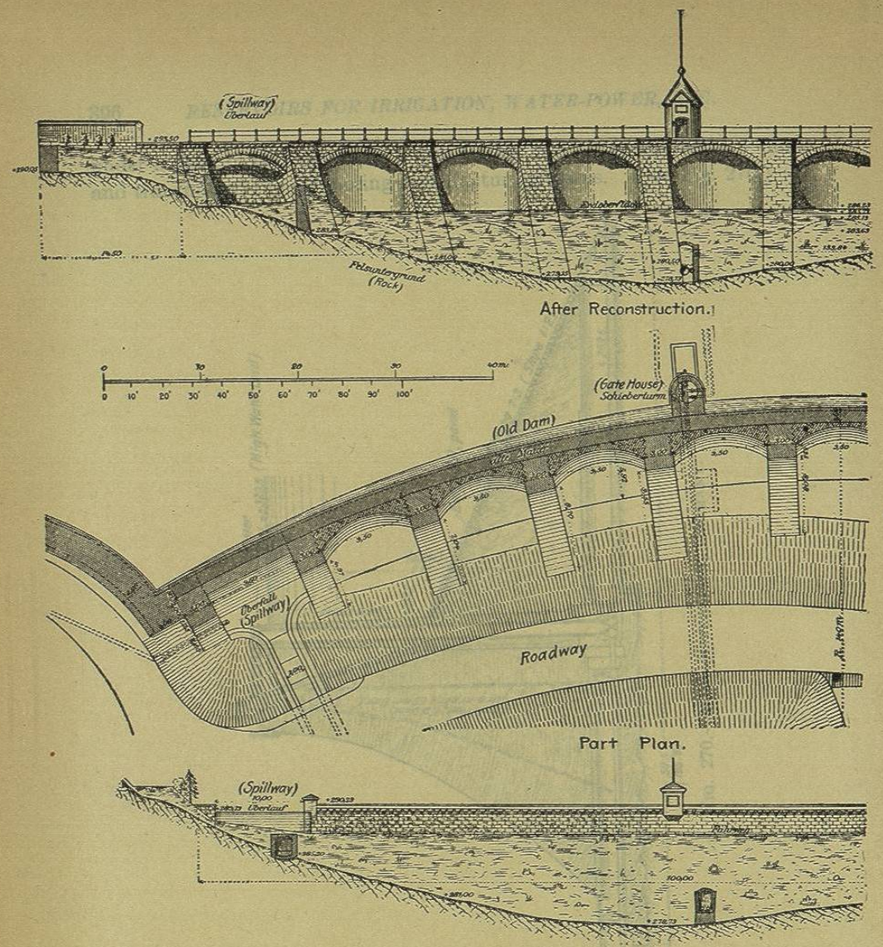


FIG. 271.—LENNEP DAM, GERMANY.

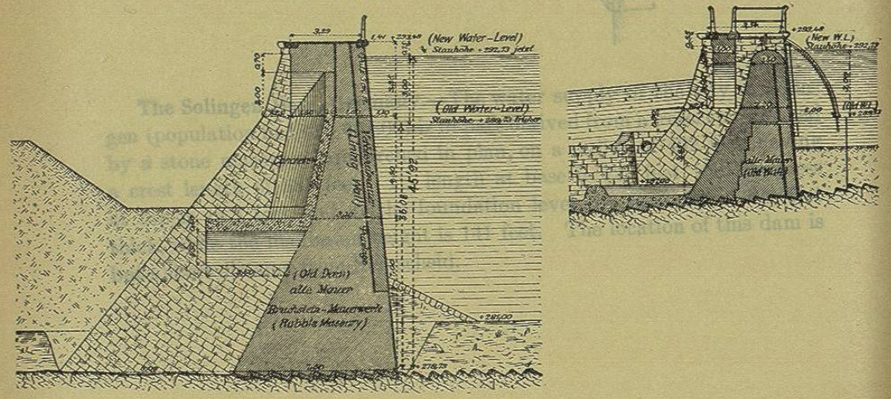


FIG. 272.—LENNEP DAM, GERMANY.

[*To face page* 397.]

The Lauchensee Dam, Germany.—This structure is one of four built by the German Government in 1892-95, for the purpose of increasing the low water flow of the streams of the Vosges mountains, and has many interesting features. It has a maximum height of 98.4 feet, is about 840 feet long on top, and is curved up-stream with a radius of 2950 feet. The crest width is 13 feet, base 65 feet, designed as a gravity structure, with all lines of pressure falling within the center third. It is composed of cyclopean rubble, laid in concrete of trass mortar, mixed in the proportion of 1 part lime, 1 part trass and 2½ parts sand, produced by crushing sandstone, which is the foundation rock of the dam.

The dam contains 37,400 cubic yards of masonry, of which 65% is stone and 35% mortar. The masonry cost $5.38 per cubic yard, the total cost of the dam being $243,750, including $23,750 for an earth embankment placed against the down-stream side of the dam four years after the masonry was completed, when it had been demonstrated that there were no defects in the masonry structure. The purpose of this embankment, which reaches nearly to the top of the dam, is to protect the masonry from the sun, it having been noted during many years' observation on the elastic movements of the dams of that region that the water pressure exerted a much smaller influence than the expansion due to warm weather. The embankment is paved on the surface, and is provided with two berms.

The reservoir has a capacity of but 27,200,000 cubic feet (624 acre-feet). The average cost was therefore about $390 per acre-foot of storage capacity provided. The chief engineer of the work was Mr. H. Fecht, who contributed an article in the "Zeitschrift für Bauwesen," quoted by *Engineering Record*, August 30, 1902.

Lennep Dam, Germany (Figs. 271, 272).—This dam was originallly built in 1893 to a maximum height of 37.7 feet, with a width on bottom of 24.6 feet, and a crest width of 5.25 feet, forming a small reservoir of 32,000,000 gallons capacity, supplying the city of Lennep. The dam was curved up-stream with a radius of 460 feet, and its crest length was 416 feet. To increase the storage capacity to about double, it was decided to add 10 feet to the height of the dam, and this addition was recently completed in a somewhat remarkable manner by building a series of buttresses or counterfort walls on the down-stream side, 41 feet apart from center to center, each buttress being uniformly 9.84 feet thick. At the section of maximum height the buttresses extended down a distance of 26.24 feet from the original toe of the dam, and at the level of the crest of the old dam the buttress is 10.66 feet wide. An addition to the top of the dam. 10.7 feet high, was built in trapezoidal section, starting with the crest width of the old dam and narrowing slightly to the top. A series of hori-

zontal arches were sprung between the buttresses at the crown level and at mid height to transmit the pressure to the buttresses, and at the same time vertical arches of concrete were made between the upper and lower horizontal arches. The masonry of the buttresses was laid in courses so inclined as to be normal to the lines of pressure, as in the Remscheid, Urft and other German dams. The mortar used in the concrete and in laying the masonry consisted of 1 part Portland cement, 1 part slaked lime, 1½ parts trass, and 4¾ parts washed sand. Lennep is a small city of 14,000 inhabitants, in the neighborhood of Remscheid.*

Other German Dams.—The following list of masonry dams, designed after what may be termed the Intze type, with earth embankments on the up-stream face, is quoted by Mr. Edward Wegmann in his work, from an article on masonry dams by H. Bellet, Civil Engineer.

Name.	Location.	Height in Feet.
Salbach	Ronsdorf	78.5
Lingese	Marienheide	80.5
Eschbach	Remscheid	82.0
Bever	Hükeswagen	82.0
Fuelbecker	Altena	88.7
Jubach	Meinerzhagen	91.3
Glörbach	Breckerfeld	105.4
Hasperbach	Haspe	111.0
Herbringhauser	Lüdringhausen	112.0
Oester	Plettenberg	119.0
Henner	Meschede	125.0
Ennepe	Altenvörde	135.0
Sengbach	Solingen	142.0
Queis	Silesia	148.0

Dams in Austria.

The Komotau Dam, Austria.—The highest dam in the Austrian Empire was built near the city of Komotau, Northern Bohemia, near the German frontier, on a tributary of the river Elbe, in 1901-1904, for the water supply of that little city, whose population in 1900 was 13,050. The dam forms a reservoir of 24,710,000 cubic feet capacity, or 568 acre-feet. It has a maximum height of 139.4 feet, or 116.5 feet above the stream bed, and carries a maximum depth of 111.5 feet of water. It is 508.5 feet in

* *Engineering News*, August 29, 1907, with illustrations from the "Zeitschrift für Bauwesen."

length on top, 170.6 feet long at bottom, is 98.4 feet thick at the base, and 13 feet on the crest. It is curved in plan, on a radius of 820 feet. The total volume of masonry is 53,600 cubic yards, consisting chiefly of cyclopean rubble, made of large blocks of gneiss embedded in Portland cement concrete. The crest of the dam is ornamented with dimension stone of granite, cut and laid in mortar.

In this dam, as in many of the newer German dams, a facing of asphaltum and tar was applied in two layers, held in place against the up-stream slope by a layer of concrete, dovetailed into the main body of the dam. A drainage system in the body of the masonry was also provided to carry off possible seepage, by means of 3-inch vertical pipes with open joints, placed in small shafts, built 6.5 feet apart, 3.3 feet in from the water-face. These connect at the bottom with larger pipes discharging any water so collected into a drainage gallery leading to the down-stream side. In this manner it is intended to prevent the possibility of the existence of upward pressure in the interior of the masonry. This treatment of masonry dams is becoming quite universal among European engineers and is being adopted in the United States.

The dam, though known to the outside world by the name of the city it supplies, is locally named for the Austrian Emperor, Franz Joseph.

Dams In Belgium.

The Gileppe Dam, Belgium.—No masonry structure of modern times has so great a section as this, and few if any contain such an enormous mass of masonry, the total volume of which is 325,000 cubic yards, all of which was put in place in six years, from 1870 to 1875 inclusive. The dam is most imposing in appearance, but it has a vast excess of masonry beyond safe requirements, the effect of which is to place additional stress upon the foundation masonry without increasing the stability. The principal dimensions are as follows:

Maximum height	154	feet.
Length on top	771	"
Breadth on top	49	"
Breadth at base	216.5	"

The dam is curved up-stream on a radius of 1640 feet. It was designed by M. Bidaut, Chief Engineer, who occupied nine years in the preliminary studies before plans were submitted to the Belgian Government, by whom it was erected to regulate the flow of the Gileppe River and provide a pure-water supply for the cloth manufactories at the city of Verviers.

The reservoir formed by the dam covers an area of 198 acres and impounds 3,170,000,000 gallons, or 9730 acre-feet. The mean depth is 49

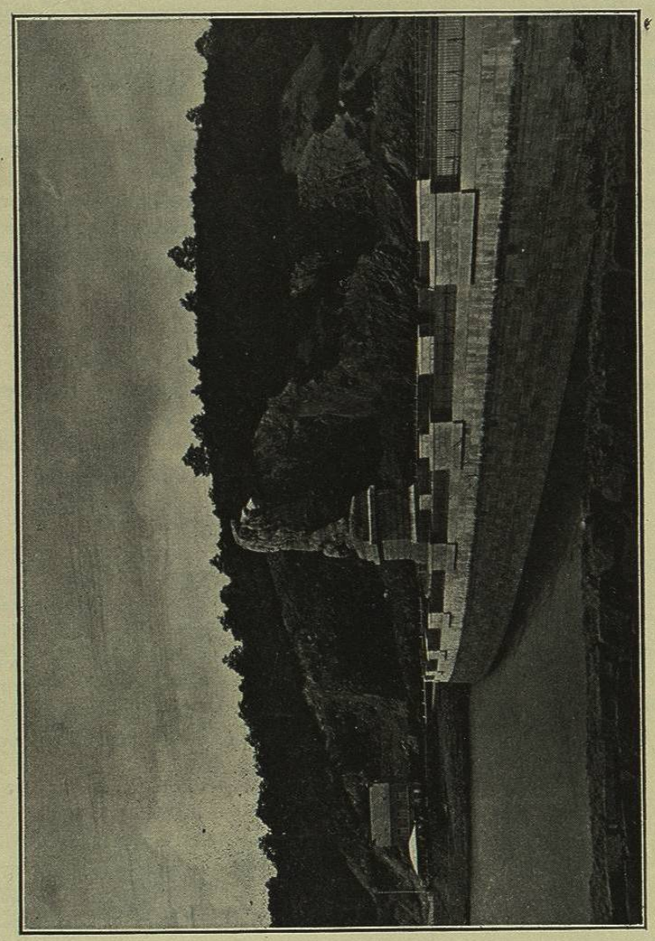


FIG. 273.—GILEPPE DAM, VERVIERS, BELGIUM. 400

feet, or just one-third the maximum depth. The capacity of the reservoir is about one-half the average annual run-off from 15.4 square miles of watershed.

The masonry is rough rubble throughout, of sandstone quarried on the spot. The dam is surmounted by a cyclopean statue of a lion sitting on a pedestal. An ample carriageway is provided across the dam.

Considering the great thickness of the wall and the care taken in its construction, it was a great disappointment to find on filling the reservoir that it leaked quite considerably. This leakage gradually diminished and is of no importance as affecting the stability of the dam.

The entire cost of the dam was $874,000, or $89.83 per acre-foot of storage capacity.

DAMS IN GREAT BRITAIN.

The Vyrnwy Dam, Wales.—Since July 14, 1892, the city of Liverpool, England, has been chiefly supplied by water from a large storage-reservoir in the mountains of Wales, 77 miles distant, formed by a monumental dam of masonry erected across the Vyrnwy valley, in 1882 to 1889. The dam has a top length of 1172 feet, is straight in plan, and has a maximum height of 161 feet from foundation to parapet. It is used as an overflow-weir over its entire length, and its profile was designed to offer additional resistance over that presented by water-pressure alone. An elevated roadway is carried across the dam on piers and arches, above the level of flood-water, which adds greatly to the architectural effect and ornamentation of the imposing mass of masonry. The great wall is composed of cut stone. The base width of the dam is 117.75 feet. The back-water level below the dam is 45 feet above its base.

The total volume of masonry in the dam is 260,000 cubic yards, which was laid with such extraordinary care that its average cost was nearly $10 per cubic yard, in a country where materials and labor are of the cheapest.

The base of the dam is founded on a hard slate rock, and one end of the masonry is built into the solid wall of bed-rock on the side of the valley. At the other end, however, the rock was so deeply overlaid with a deposit of bowlder clay that the masonry was connected with this material by a puddle-wall of clay recessed into the masonry.

The general dimensions of the dam are as follows:

Total length on top	1172 feet.
Maximum height on top of roadway parapet	161 "
Height, river-bed to parapet	101 "
Height, river-bed to overflow-level	84 "
Greatest width of base	120 "
Batter of water-face	1 to 7.27 "