tion free from horizontal thrust very desirable for this portion of the viaduct.

On account of the high altitude—4,330 ft. above sea level—the structure is subjected to very great variations in temperature and special provision had to be made for expansion. The roadway over the arch was therefore separated from the approach spans by the use of double piers over the arch abutments with an expansion joint between. The high intermediate piers connected rigidly to the girders were designed so as to be sufficiently elastic to allow for longitudinal expansion of the deck without overstressing them.

The main objects to be fulfilled in the design and construction of this bridge were: (1) To keep the actual stresses as low as possible and at the same time (2) to save as much material as possible. On account of the relatively small live load, as compared with the dead load, these conditions could readily be complied with by the use of an arch composed of two ribs instead of a solid barrel arch.

By designing the deck of the approach spans as a series of continuous girders, transmitting the wind stresses directly to the end abutments and to the large double piers over the arch abutments, the approach piers could be consistently made of light construction consisting of two main posts of reinforced concrete tied together by struts of the same material. By this method of design, heavy stresses were transmitted to the double piers, and it was therefore necessary to connect each pier to these posts with a solid transverse wall.

In order to secure greater stability, against wind pressure and the buckling action of the arch acting as a column, the exterior faces of the arch ribs were given a 4% batter or flare from crown to the abutments. The inside faces of the ribs were also given a batter of 2½% toward the abutment, in order to secure the additional required strength toward the springing.

Live Loads.—The live load used for the design of the viaduct consisted of one train of two electric locomotives each of 65 tons maximum weight, followed by an unlimited number of freight cars.

For designing the longitudinal girders over arch and approaches and the roadway slabs an additional live load was added in accordance with the formula $\frac{15-l}{100}$, in which l is the span in meters. Temperature stresses due to a range of ± 27° F. were considered in design, also shrinkage stresses due to a further decrease of 36° F. The allowance made for horizontal traction or braking loads was equivalent to one-seventh of all wheel loads. A wind load of 20 lb. per sq. ft. for loaded structure and 30 lb. per sq. ft. for the structure alone, was considered in design. The area exposed to wind was considered as follows: Face of girders, twice the area of front face of columns, one and one-half times the front face of double piers, and for trains a surface 10 ft. high, with the pressure acting at 6½ ft. above the rail.

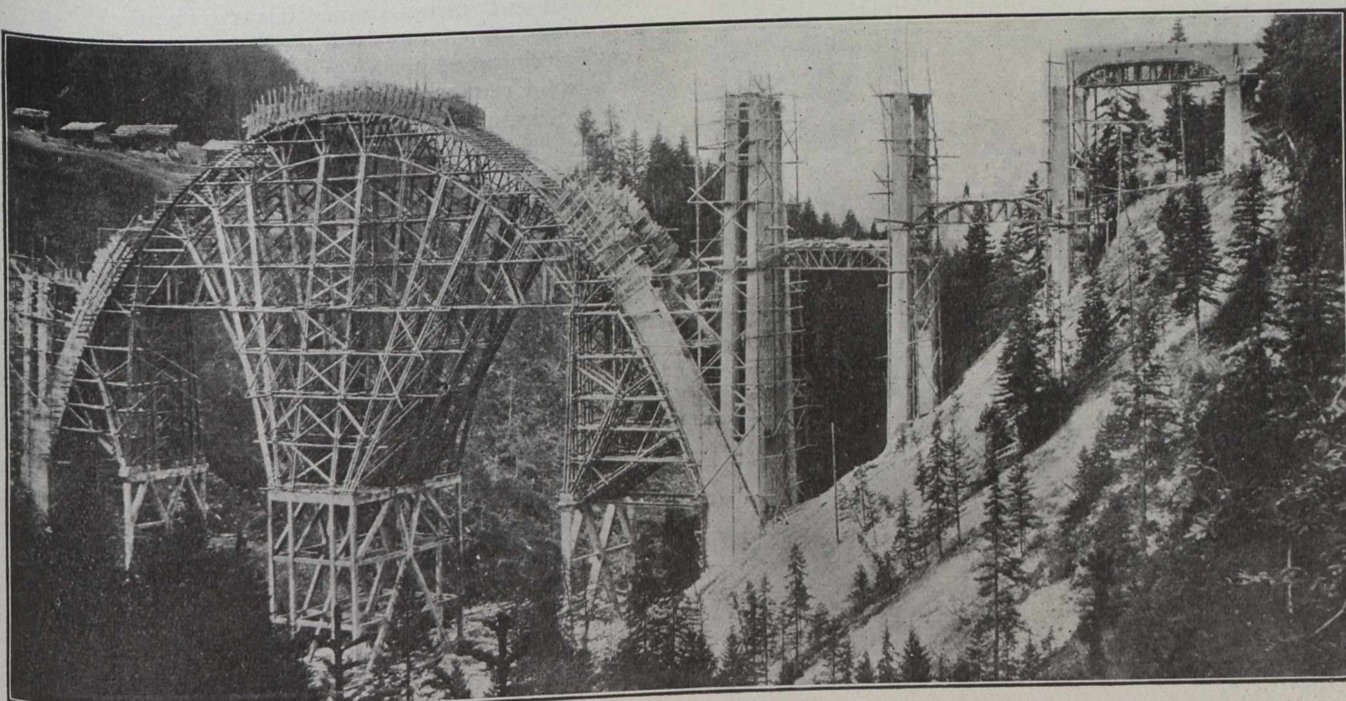

Fig. 4.—Completed Centering for Arch Span.

Unit Stresses.—The allowable unit stresses used in design were for dead and most unfavorable conditional live load 495 lb. per sq. in. compression in concrete and 14,200 lb. per sq. in. in steel, while for combined stresses due to dead and live loads shrinkage, temperature traction and wind the compression in concrete allowed was 639 lb. per sq. in. and the stress in steel 17,040 lb. per sq. in. The allowable shear in concrete was 57 lb. per sq. in. The modulus of elasticity of concrete was taken as 2,800,000 lb. per sq. in. and the ratio Es/Ec as 15. All concrete was sampled and tested daily and when poured as a plastic or wet mass was required to have a strength of 2,556 lb. per sq. in. at 28 days, and 3,550 lb. per sq. in. for dry mixed or slightly moist concrete.

In the arches and columns and those parts of the structure where the stresses are mainly compressive, the stresses were computed by the Ritter method. For members subjected to bending, the compressive and tensile stresses were computed by Christoph's method, due allowance being made for the strength of concrete in tension