# APPENDIX TO THE ABOVE NOTES.

By C. A. W. Pownall.

[Read May 27th, 1891.]

Mr. James Forrest, Assoc. Inst. C.E., and Secretary to the Institution, has most kindly collected information as to the effect of earthquakes on ancient buildings in the Mediterranean basin. Extracts from letters addressed to him are given below.

A gentleman who has made the subject of earthquakes a study, wrote to Mr. Forrest:—

"It appears your correspondent wants to know about old works which were built before seismology was thought of. He may be referred to:—

(1). "Ancient Engineering and its Methods," by R. Mallet.

(2). "The Engineer," 12th November, 31st December, 1875.

(3). "Earthquakes, or Aseismic Building," The Engineer, 23rd August, 1883.

(4). "Palmieri's Eruption of Vesuvius (Mallet's Introduction thereto, London, Asher & Co. 1873).

Numerous old Roman Viaducts are illustrated and described in:—

(5). "Gauthey's Traite de la Construction des Ponts, 1809.'

From a gentleman at Marseilles who had peculiar facilities for obtaining information on the subject, Mr. Forrest received the following:—

"I have not been able to obtain any documents relative to constructions designed to resist earthquake shocks, and all the architects whom I have consulted on the subject assure me that the Roman remains hereabouts contain no particular provisions in this respect, the country not being much subject to volcanic disturbance. The Roman aqueducts and innumerable works were constructed either of very large stones laid dry, or of pozzolana concrete. The Roman remains occurring along the Mediterranean littoral exhibit foundations entirely in pozzolana concrete. They sought to establish foundations of large works on the solid rock. As a matter of fact I noticed at the time of the earthquakes of two or three years ago that all the houses at San Remo which were founded on the rock remained upstanding, while those built on the ordinary soil (alluvium) were overturned."

From an Italian Engineer Mr. Forrest heard:—

"I have been told that neither Vitruvius nor Frontinus have

ever mentioned that any special provision had been made by the builders of the Roman viaducts and aquaducts; on the contrary, Claudius' aquaduct having been built with unconnected foundations, that is to say with separate foundations for every pillar, wanted only to be repaired, but we do not know whether it had been damaged by earthquakes or only by the earth's subsidence. The Emperor Septimus Severus had it repaired, sustaining the damaged imposing travertino* arches with brick masonry."

Another communication to Mr. Forrest was:—

"After much labour in the quest of information regarding the measures adopted by the ancient Romans to protect their aqueducts and other structures against the ravages of earthquakes, nothing can be traced in reference thereto; so I can only give some opinions of Professors and men of science of this city and of my personal impressions. Even the latest work, for example, Lanzini's fundamental work on the aqueducts of Rome, contains nothing. That the restoration of the aquaduct Claudius in the time of the Flavis and still further in that of the Severianis (Lanzini, pp. 146-150) shew results of damage caused by earthquakes perhaps, but not expressly certified.

"About the commencement of the 18th century a severe earthquake-shock felled two of the arches of the Colosseum of Rome, one storey of Nero's Tower, and several houses.

"It appears that more of practical than theoretical engineering was practised by the ancient Romans. Their masons were excellent, as is well-known; their structures were ponderous as is seen by the Termini di Caracalla, the Palentine buildings, and the before-mentioned Colosseum, where two walls are raised parallel and afterwards filled in with concrete composed of broken tiles, puzzolano, and lime. The lime was slacked several years before use, and the arches in the above-named structures were built of large tiles 57 centimetres square and

* Travertino is a white calcareous building stone found near Rome.

four centimetres thick and finely jointed, which would afford more friction in case of undulatory disturbance than the small bricks employed at the present day. Nothing was spared as regards labour and materials; the aqueducts and other structures were built by the slaves—their payment being strokes of the stick—and the materials were produced by volcanic cause long before Rome was thought of. The volcanoes are situated a few miles from Rome, and the beautiful lakes of Albano and Nemi were formed from the craters.

"The subject is a very interesting one and I shall be glad to give you any further records that I may gather from time to time."

The writer of this paper desires to acknowledge his obligation to Mr. Forrest for the great kindness he has shown in obtaining and forwarding the above.