# EXTRACT FROM THE REPORT OF THE COMMITTEE APPOINTED TO PROPOSE BUILDING REGULATIONS FOR ISCHIA.

(Relazione della Commissione per le Prescrizioni Edilizie dell' Isola d'Ischia instituita dal Ministro dei Lavori Pubblici (Genala) doppo il terremoto del luglio 1883.—(pp. 43-86).—Roma, 1883.]

## Districts more or less Dangerous.

Based upon the above-mentioned considerations we can now attempt to draw, at least approximately, the more or less dangerous zones of territory, in order to obtain a rule to be followed, when the new plans regulating the future sites of dwellings shall be established. It has already been observed that it will be perhaps impossible to dissuade many of the inhabitants from remaining on their original property, although such has been subject to more or less damage: it will therefore be the duty of the higher authorities to indicate, as was done shortly after the catastrophe for the principal groups of wooden barracks, either the most dangerous zones to be abandoned or the safest ones to be chosen for the said building sites.

In order to render the following observation more intelligible a small geognostic-seismic map, to a scale of 1 : 50,000 has been annexed. It contains different special indications relating to the said zones, which are distinguished from each other by yellow colours of varying intensity, the principal groups of ruins being noted in vivid red. The scale is really too small, but it will suffice for the present purpose.

It is evident, after all that has been said, that the zone, which runs in a East-West direction along the supposed line of fracture to the Northern foot of Mount Epomeo along the small valley of the baths of Gurgitello, Higher Casamicciola and the *fumarole* of Mount Cito, must be considered as dangerous in the first degree. The zone along the other supposed normal line of fracture, which, starting from the centre of the Epomeo, cuts the first line on the side of the said Mount Cito and Higher Casamicciola, and which, running parallel to the small valley of the Rita torrent, passes through the sea-shore of Lacco and the sources of the Santa Restituita, is also to be regarded as dangerous. If we really admit that the focus, which seems now to exist under this northern part of Epomeo, were increasing in intensity, Mount Cito or some place in its vicinity, would be the first point of a possible erruption of lava or of small stones, and in such case lava would of course flow through the small valley of the Rita towards the shores of Lacco.

The above indicated dangerous zone running East-West may be limited towards the East by the trachytic lava of Mount Tabor, which, coming from Rotaro, flowed to the sea, where it now forms the solid point of Guardiola, upon which is situated the cemetery of Casamicciola. But towards the West, at least in the higher part of the hills along the road to Forio in the supposed prolongation of the line of fracture, the exact limit is not easy to be determined. In fact we notice that in the higher suburbs of Forio, which are two kilometres from Mount Cito, the destruction has been very considerable. This, however, is more probably due to the elevated position of those suburban structures and to the very bad method of their construction. It is therefore possible to limit the very dangerous zone, in this higher part, a little beyond Mount Cito in the so-called (Mud) Tango region. With regard to the lower part, that is to say, that towards the sea-shore of Lacco, if we consider the quantity and the kind of the *débris*, the dangerous zone

may be limited to the region of Mezzaira, at the foot of the first heights of the lava rocks of the Marecoco, which rocks towards the west constitute the whole promontory of Mount Zale.

Therefore, after having admitted the maximum of danger to be on the East-West line at the foot of Epomeo, a line which might be considered as the principal origin of shocks, we may infer that there is a gradually diminishing danger, towards the sea-shores of Casamicciola and Lacco, on which buildings have very little suffered. However, we believe that the hilly region about 1 kilometre broad lying between the sea and the mountain, the soil of which consists only of tuff and clay crossed by torrents and brooks, with steep banks, which was formerly covered with houses, villas, and hotels, and where during the catastrophe almost everything was destroyed, possesses conditions too dangerous to allow reconstruction on a large scale of the new town and of new buildings. Therefore the whole hilly region, from Mount Tabor on the East to the brook of Mezzaira on the west, should not be used as a site for buildings. The exceptions are perhaps some parts of the plain, as for instance round Savota, as well as within the lower zone on the sea-shore and certain places near to this situated in the so-called region of Perrone, which enjoy special conditions of relative security and of which we shall speak hereafter, as it is one of the favourable localities to be chosen for future constructions. The whole of the dangerous zone has been painted dark yellow in the annexed map.

With regard to the remaining territory in the communes subject to earthquakes, where the danger has not been so severe as in Casamicciola, there is no distinction to be made, and it is therefore all painted light yellow. The limit is of course only approximative. In order to have an exact seismic map such as may give some precise and useful rules to the builder, it would be absolutely necessary to possess a map on a much larger scale and to make a special geognostic-seismic

study, which would require a great deal of time. There will now be a proper opportunity for such study while estimating the damage to buildings, as will be shortly done by a special committee, to which there should be attached a person competent in seismic matters. In default of a regular map on a large scale, some carefully executed sketch of the most interesting places and ruins might be used, reserving a more complete work for another occasion. In the meanwhile, when such data shall be obtained should there exist some doubt as to the convenience of constructing on a given point, the question could be discussed as a special case.

After having briefly spoken of the more or less dangerous places, which must be avoided, we can now say something of those which present a certain degree of security. But as the important case before us is only that of Casamicciola and Lacco, we will limit our observations to these two places.

Knowing that buildings constructed upon solid lava are more secure than those lying on tuffaceous and clayish soil, it would be therefore better to choose those zones, where the lava appears more or less on the surface, and which are painted pink in the annexed map. Such for instance are on the east of Casamicciola the slopes of Mount Tabor and other places over Castiglione, on the west the promontories of Mount Zale and Mount Vico. But such places formed of lava are generally either sterile or steep, or situated at a distance from the present centres of habitations, which have been established on the most fertile grounds. That particular attachment to inherited estate, so pronounced amongst the inhabitants, must also be taken into consideration. For this reason an emigration of people from fertile places, which have been formerly so well cultivated, to sterile and distant localities must be considered as impracticable.

With regard, then, to soils formed of lava and other solid rocks which are to be preferred to those of softer tuff, clay,

alluvium, and sedimentary rocks in general, it is here necessary to add a general note; that in reality the security is there only relative and not absolute, especially in the case of very violent shocks. Solid rocks, like granite or a rather thick stratum of lava, do not remain unmoved during a shock; but as they move like one mass they act towards the building in the nature of a solid foundation, by which even during the most dangerous motions the building is lifted and lowered *en bloc*, while on the other hand stratified soils and soils inconsistent in character become broken and are liable to open, causing the greatest danger to the buildings resting on them.

Frequent examples of such occurrences even in Italy, can be quoted; as for instance during the Bellonese earthquake of 1873, in which buildings constructed on alluvial stony ground suffered very much, while little or nothing happened to those resting on solid banks of eocene gravel. The same thing happened elsewhere, as in Calabria during the very strong earthquake of 1783, when districts having a substratum of pure granitic rocks which form the frame work of that region, suffered less than those of rocks covered with tertiary and quaternary soil. The security was, however, far from being absolute even on granite, the most violent shocks having overthrown everything resting on such rocks.

A similar consideration may therefore be applied to the eastern part of the island of Ischia, where, though lava is not everywhere to be found, it is frequent, although mixed with tuff, and where but little damage has been caused. But this may in part be owing to the greater distance of this locality from the centre of commotion, which was at that time beneath Epomeo. It may also depend upon the want of continuity in the ground lying between these places. If everything could be foreseen, however, it is not impossible that a new and more violent shock might produce, even in the lava districts, destruction which up to the present those districts have been exempt from.

With regard to the localities to be preferred, one more point remains to be noted, and that is the possibility of a sea-disturbance (*maremoto*), a phenomenon which takes place when the commotion totally or partly orignates under the bottom of the sea. In such a case the water rises instantaneously, and into great fury, often to the height of several mètres, overflowing the lower land, and although it may retire with equal rapidity, it causes greater damage and loss of human life than even the earthquake itself. We have had severe examples of this on tke American Pacific Coast and lately at Krakatoa in the Sunda Straits, where the sea rose 100 feet, causing in Java and Sumatra enormous destruction, while the waves which were produced spread until they reached Madagascar, India, and America. In the Mediterranean such vast wave propagations have not yet occurred. Sometimes, however, near to the centre of commotion, disastrous risings of the sea have been noticed, as during the earthquakes of Calabria of 1783, and even in the most recent ones near Vesuvius and in Pozzuoli.

In Ischia, according to ancient records, such disasters accompanied the earthquakes of the fourth century before the Christian era. During the late catastrophe of 28th July the sea in Casamiciola and Forio was somewhat agitated, without rising and invading the land. A muddy discoloration of the sea, a lifting of the bottom of the Gulf of Torio, and certain changes in the Epomeo have been spoken of, but His Majesty's ship *Washington*, of the Hydrographic Institute, has ascertained that no sensible variation occurred, with the exception perhaps of a rising of the sub-marine bank near Ventotene. Such want of connection between the shocks of Casamicciola, and the bottom of the sea, may to a certain extent be explained by the situation of the centre of commotion in Epomeo, the lateral action of which and that directed from its summit did not tend to raise the sea-bed.

However, such favourable circumstance may not continue,

and should the centre of commotion move towards the north, the disturbance might become a submarine one. In fact it has already been noted as an hypothesis that the line of axial fracture is N.-S., or rather N.N.W., in a direction which runs parallel with the small valley of the Rita. This depression appears to continue below the sea, as has been there ascertained by soundings, and such a line of fracture pointing towards the great extinct continental volcano of Rocca Monfina and possibly splitting into branches towards the Ponzie Islands on the East, might become in its turn a line of future commotions ; in which case the sea-shores of Lacco and Casamicciola, in the regions of Casamonte and Annunciata, would occupy very dangerous positions. This is only a simple hypothesis suggested by the exposed geognostic conditions of this volcanic region ; but extreme prudence demands it should not be entirely neglected. We consequently conclude that, for the purpose of seaside residences, those places ought to be chosen which do not lie quite at sea-level, but at an elevation of at least 10 or 15 mètres above it. Returning to the consideration as to the localities to be chosen for Casamicciola and Lacco, a few places appear to be sufficiently favourable.

Beginning from the west, attention is drawn to a locality situated between Lacco and Forio, and more precisely between the houses of Mezzavia and Spadara, at the foot of the height of Marecoco, where the soil, which lies from 50 to 70 mètres over the sea-level, is principally formed of lava, which also constitutes the great promontory of Mount Zale. This locality, being in the angle formed by the two supposed lines of fracture E.W. and N.S. should be, in case of a cataclysm, relatively safe, and in fact it has been indicated as good by Johnston Lavis of Somma-Vesuviana, who made studies and wrote on the last earthquake. However, when examined, we there found many irregularities in contour, and discovered that the level area over the lava is not very extensive ; should, therefore, the number of houses be greatly increased it would be neces-

sary to occupy some sloping ground or other localities bounded by the neighbouring eastern heights.

The other locality, which is really more noteworthy, is that which might be used for the reconstruction of Casamicciola, where the greatest part of the homeless population is now iliving, and where also places for new bathing establishments should be founded, in order to reap the advantages offered by ts famous hot springs. Here and in Lacco, the sea-shore, as has been seen, was to a great extent exempt from severe destruction and might therefore be still inhabited ; especially if instead of the present dangerous kind of buildings with vaults, a more rational system, adapted to countries threatened by earthquakes, were introduced.

Several groups of barracks, such as those called Umberto, S. Severino, and Genala, might be used without counting that called Savota on the Gran Sentinella hill about 100 mètres over the sea-level. The two quarters Umberto and S. Severino being somewhat near to the small valley of Gurgitello, are, however, still somewhat a centre of danger, besides which they are only a few mètres distant from the sea ; it would not be therefore advisable to propose them as sites for permanent buildings.

There remains the locality more to the east of Casamicciola, which is now the greatest quarter for barracks, called Genala, and which lies in the above-mentioned region of Perrone.

At this place the ground, from the angle of the country road to the promontory on which the cemetery is situated rises, shows elevations up to 15 mètres and more above the sea. Here are situated the houses of Maresea, Russo, and Lombardi. That of Russo, recently occupied by the office of Civil Engineering, may be said to be the only one which did not suffer any damage. The soil is here not composed of solid lava, but of a conglomerate of pieces of scoriæ and pumiceous tuff, which, however, is strongly cemented, as may be seen in the

perpendicular precipice at the sea-side. On its higher part it is almost everywhere covered with a layer of about one mètre of puzzolana, which is considered to be excellent for building purposes. The total available area from the sea to Mount Tabor, exceeds 10 to 12 hectares, a part of which, to the south of the country road of Jochia, is now occupied by the said Genala Barracks, while on the north, that is to say, along the steep cliff close to the sea, several factories exist, which shut out the sight of the sea and spoil the place, but could be, with no great difficulty, removed. Another advantage of this eastern corner of the plain of Casamicciola, is, that it lies at a maximum distance from the seat of commotions, that is to say, from Mount Cito and the small valley of the baths, its relative security being thus increased. It might be observed that its extremity is not far, perhaps 300 mètres, from the cemetery; but the situation of this, which lies beyond the line of the promontory of Guardiola, and the predominance of west winds, prevents any inconvenience on that account; and indeed, even in the most critical times after the disaster, no unpleasant sensations at all have been observed on this score.

Such a locality must therefore be included in the new plan regulating the position of reconstructions.

### System of Construction used up to the Present in the Island of Ischia, and its Disastrous Consequences.

Having examined the action of earthquakes principally with respect to the geological structure of the island, there remains to be considered the system of building construction employed up to the present, which has been a very powerful agent in causing destruction.

Beginning with the foundations, it is a fact that, while especially in a hilly region composed of friable tuffs in inclined strata and crossed by torrents, they should have been executed with considerable care, such precautions are seldom discoverable. Many houses and hotels were built on the sides of

steep slopes of little security, or on false foundations not reaching a solid bed, and only kept together by weak supporting walls. Such circumstances have already been mentioned, and if they have not been always the immediate cause of destruction, they contributed to the same.

All the buildings, without exception, from the humble farm-house to the most elaborate edifice and to the churches, were entirely constructed in masonry, and in such a manner as would have been used in countries where earthquakes were unknown. In fact there were many houses with three and four stories above the ground; and many of them, especially those belonging to farmers, had a cellar which served to keep wine, this being a necessity in a region where almost the only industry is that of manufacturing wine for export. Almost all the stories, even the third stories, were covered with masonry vaults. It was only in the higher stories of a few houses that ceilings were supported by chestnut beams, and even these were not fixed deeply into the walls. In the town many houses had their roofs covered with ordinary tiles, not attached to the trusses, while the farm-houses, and those in the country in general, were covered with terraces—very useful in such places for collecting rain-water and especially for drying fruits upon—but, nevertheless, very heavy. They consist of a very thick pavement or layer of small stones, on which "battuto," a kind of mortar, is laid which is rendered very hard by continual stamping with rammers. But such a kind of covering, which is often as much 0·30 mètre thick, is very heavy.

The vaults, with the exception of those of churches or other important buildings which were waggon vaults, were generally segmental vaults having a very low curve, especially in their central part, where although covered with a very heavy pressed pavement, they were often almost flat. They were also generally badly constructed, with irregular materials, put together without any order, with little and very inferior mortar. Iron keys were not used except in some of the houses, which had

been damaged by previous earthquakes, such as that of 1881. The walls which were mostly constructed with the common tuffaceous stones of the island, were also imperfect, as the stones used were not always squared but often unwrought and quite irregular. Sometimes rubble was thrown into the middle of the walls, so that some of them have been observed to have been split into two along their length. The mortar was often very inferior, that is to say, it contained little lime, but clay or earth was substituted, as might be expected in an island, where lime had to be introduced from the mainland. In many masonry constructions it has been noticed that the mortar had been used in an almost dry state, which was partly owing to general scarcity of water.

This kind of construction was indeed very convenient and economical for a country possessing a very warm southern climate, where stone was plentiful, but where there was a want of lime and timber. Brick masonry, so resistent and to be recommended for earthquake countries, was only new in rare cases, perhaps on account of its relative high price. Bricks, however, are manufactured on the island. These are sold in Naples at the price of 37 lire per 1,000, while their price in Ischia is 25 lire. This industry of bricks, tiles, and pipes, as practised now in Casamicciola is, however, very curious. As we have seen, there is no want of clay, which was formerly very industriously excavated in small galleries and which produced bricks much esteemed for their lightness. But now the excavation of clay has become difficult, so that in order to continue this industry clay has to be imported from Gaeta. The fuel used is wood brought from the coast of the mainland, while the bricks produced are still exported and sold on the continent. This industry has therefore become in Casamicciola unremunerative, and is only kept alive by force of habit. Of the 45 and more furnaces which were formerly worked only about half are now active.

The lime is fat, and is imported from Castellamare, and costs

laid down in the island 42 lire per 1,000 kilograms, to which price must be added the cost of transport on donkey back to the different places of consumption.

Thick masonry of square tuffaceous stones of the island, more or less dressed, may be calculated at about 12 lire per cubic mètre. With such materials, an ordinary house, built as is customary in the island, with vaults and any kind of roofing, having two stories above the soil in addition to a cellar, may have cost from 70 to 80 lire per square mètre of area covered.

The use of ceilings of chestnut wood instead of vaults does not make a great difference, but it may perhaps have somewhat lowered the cost.

Chestnut beams of average size usually do not cost more than from 85 to 90 lire per cubic mètre, that is to say somewhat less than foreign fir; and of this hard and very durable timber, which will last for one or two centuries, unlimited quantities can be obtained from the Italian peninsula and especially from its southern provinces. Such conditions are very favourable for the substitution of ceilings for vaults, which, as was natural, have been the principal cause of the loss of life.

With regard to the value of iron ties, which especially after the earthquake of 1881 have been proposed for several buildings, they have unfortunately during this last vertical commotion been shown not to have been very valuable, and in many instances they have created destruction, perhaps on account of their point of connection with the masonry not having been sufficiently complete. Bad examples of the kind have been noticed in several buildings near the square of the bathing-place and especially in the Villa Di-Mayo, which in spite of its iron ties, has been completely destroyed.

With respect to the orientation of buildings, that is to say in the matter of their having their longer sides or their cross walls placed in the predominant direction of the shocks, it does not appear to have much mattered, as during the com-

motion everything was equally overthrown; but according to observations of Professor De Rossi, it seems certain that in 1881 proper orientation has been of advantage to several buildings, as for example to the parish church of Higher-Casamicciola, which at that time was but little damaged. The violence of the shock of 1883 on buildings, which had already more or less suffered, destroyed everything: but notwithstanding this a rule for good orientation may be of some value.

With regard to the probable direction of the shocks, the same Professor considers from observations made that the same is generally normal to the lines of fracture of the soil-which would be East and West at the foot of Epomeo and the above-mentioned radical direction N.-S. The exertion of internal fluids acting against the sides of these fractures, lift them a little, producing therefore a shock in a direction normal to their length. Consequently according to the said Professor, a good rule, which he believes was very efficacious in 1881, would be to place the most resistent side of a building normally to the nearest line of fracture.

Finally, among constructions, which have more or less suffered, have been retaining walls on the sides of roads, walls which support the soil cultivated on the slopes of hills, en, closing walls, which have been dry and very badly constructed by the owners of properties facing the numerous paths. The destruction of these small supporting walls was enormous and this constitutes a not unimportant part of the damages to be repaired, damages which are partly due in many cases to the very bad and primitive system of construction. This matter is for the island a very important one and consequently it is necessary to provide against similar occurrences in the future.

## Conclusion on the observed Seismic Phenomena and the necessity of a Geodynamic Observatory in Casamicciola.

From what has been observed in the preceding chapters with regard to the geognostic constitution of the island of Ischia,

and to the phenomena connected with earthquakes and their effects, *we may now conclude that*, under the island and especially at the northern basis of the Epomeo near Casamicciola, a focus of seismic commotions really exists. Its activity, although having been dormant for long intervals, was revived in the second half of this century, showing up to the present time an increasing energy, *and that*, although the science of earthquakes has not yet reached such a high development that it warrants positive assertions as to the probability of future commotions, the possibility at any moment of their repetition must be admitted. It is therefore consequently necessary to constantly observe and take all possible precautions, in order not, as before, to be taken quite unawares.

Among such precautions, it has been suggested that a continuous observation of the most frequent, although feeble, shocks and tremors and of other forerunning symptoms which nature often furnishes, should be made and this principally by means of some geodynamic observatory to be established on the island. One such observatory is to be established in Ischia by the Bishop: but it will be too far situated from the centre of danger, and therefore at least, another one in Casamicciola is required. This might be established at a point somewhat central in the most threatened region, such as at Mount Cito, on the hill of Gran Sentinella near the barracks of the Savota quarters, a place which lies 100 mètres over the sea, from which an extensive view of the whole threatened region from Lacco to the east of Casamicciola, as well as of the Flegrean region of the continent, and also a clear view of Vesuvius, can be obtained although at a distance of 60 kilomètres.

With regard to the future security of buildings, the faults of a bad locality and of bad construction, as well as the localities to be selected for new buildings, have been already indicated. There now remains the most important subject to be considered and that is the system of construction, which will best resist violent movements of the soil.

## SYSTEMS OF CONSTRUCTION.

The system of construction to be adopted in a country subject to earthquakes ought really to correspond to the degree of their violence, which, as we have already seem, greatly varies in different kinds of soil. We can therefore, according to the class of soil, partly vary the different proposals and building restrictions. This is exactly what ought to be done in Ischia.

After having admitted this as a first rule, we must not neglect to consider the climate and the customs of the place, as well as the materials at hand. Many details have already been considered in the preceding pages, where we have seen that, the climate of Ischia being generally very warm, strong masonry constructions are desirable. Besides on account of the abundance of tufacious rocks, which are very easily worked, constructions of masonry made of this material are, notwithstanding the high price of lime and water, still comparatively cheap. In proposing alterations, which necessitate the use of materials different from those at hand and already employed, we must keep ourselves within certain fair limits, in order not to encounter difficulties, especially with regard to cost.

If we now examine what kind of constructions would be most convenient in this region, considering security as the first object, we find indeed that more that one system might be applied. The selection, however, must also be dependent upon other considerations, as for instance the purpose of the buildings, their durability, and their relative cost.

It is hardly necessary to observe that, whatever may be the system adopted and especially in those buildings, where common masonry is more or less used, a solid foundation ought to be obtained so far as is technically possible.

In order to discuss the various special cases we could here greatly extend our considerations, and we might even refer to the argument which has already been touched upon, namely,

that relating to the security which, according to the opinion of some people, the existence of subterranean cavities or grottoes give to buildings. The comparative security of the city of Naples owing to the existence of such excavations was thus alluded to by Pliny (see note[1]), and the immunity of various other cities, as for instance Granada and Caura in Spain, Tauris in Persia, and several other towns, have been likewise ascribed by antiquity to such expedients. But a discussion as to the efficaciousness of subterranean caverns would be superfluous in this report. We consider that for the island of Ischia it is not necessary to direct attention to such special expedients which, beside being very expensive, would probably be of no use during such very violent commotions as that of which Casamicciola has given us an example. This subject has been written on at great length by Louis Tridon (see *L'Evenement*, January 3rd, 1888, *La Paix*, December 18th, 1887, *La Matin*, December 18th, 1887, *La Patrie*, January 26th, 1888, *L'Avenir de l'Orme*, December 28th, 1887), and other French journals, contain articles on the safety granted to cities around or beneath which there are excavations.

We will now briefly consider the different systems of construction.

### Simple Constructions of Masonry.

As it has been already said, constructions of simple masonry being customary and almost imposed by natural conditions, will always prevail for private buildings. Constructions of other materials, such as iron or timber, are much more safe, but as such materials do not exist in the island, such kind of buildings

[1] But also against earthquakes there is a remedy, such as those offered by subterraneous drains and great caves; indeed they leave free vent to the steam engendered in them. This has been noticed in some towns, which have been less shaken on account of the subterranean caves excavated beneath them. And the security enjoyed by them has been chiefly attributed to these caves, as for instance in the case of Naples, a city in Italy, where it has been observed that a part of it owes its security to this fact." Now-a-days it is not on these facts that such an opinion with regard io Naples is to be supported.

will be always artificial and more expensive. Should they, however, be absolutely necessary, they ought to be insisted upon in building regulations. It is, however, evident that constructions of simple masonry, and especially providing that the same are used with necessary precautions, cannot be prohibited.

It would be better to take care that constructions of masonry, after having been freed from erroneous practices in building as has already been done in other countries subject to earthquakes, adapted to the dangerous conditions of the island. It therefore becomes a question how to build well and with the best material at hand.

A long experience in Italy, and especially in Siena, has proved that brick-work is excellent on account of its resistance. Pliny has already written "latere factae parietes minore noxa quatiuntur" (walls built of bricks are shaken with less damage). However, in the island of Ischia and especially in mountainous places, native tuffacous stone will always have the preference.

It is therefore necessary that the same be employed properly, not rough and of irregular shape, but carefully cut and joined with good master. Considering, however, the inferior quality of this stone as well as the greater resistance which such walls must possess their thickness must exceed that used in ordinary constructions.

These walls are in several countries strengthened, at least externally, by an escarpment, but everybody knows that such a system is very improper, besides it offers great facility to filtration of rain water. This, however, may be prevented by giving to the same a greater thickness, and in case of little consistance of the soil by making a general platform under the building.

An important precaution to be observed is the prohibition, at least in the stories over the ground, of vaults and arches of masonry. We do not need to prove the necessity of such a measure, similar prohibitions having already been introduced

into the building regulations of every country subject to earthquakes. Such a prohibition is not necessary for subterranean cellars, which are often used in the island, as in them there does not exist the same danger of dislocation of the walls which support them[2], and this has been proved by a long experience. Instead of vaults, well constructed ceilings, like those, which are often used in the island for upper stories, must be substituted, it only being necessary that they should be stronger, better supported, and more durable.

The monolithic system of masonry, that is to say, that of cement pressed into boxing which has been tried in Lombardy and in other places and which certainly offers some advantages with regard to solidity, is not to be overlooked. But in this case the question of cost, which would be perhaps threefold that of the ordinary form of construction, and the difficulty of introducing this system into Ischia, must be taken into consideration.

It would be easier to adopt clay pressed into frames (*pise* of the French), which is much used in several Italian provinces, where clayish earth abounds at the surface. This system is therefore very economical. In other places, especially in those which have been under Spanish rule, the use of large bricks of such clay mixed with chopped straw (adobes) in order to make them massive, is very common. This material is easily disintegrated by water and does not hold well even with a roughcast of lime. It is only convenient in dry climates and only where clay abounds. We speak of this material, but without recommending it, for buildings of importance. It could perhaps be employed in the construction the outer walls or of one-storied private houses[3].

It is necessary to repeat that in this island the most natural system is that of common masonry, composed of the materials

[2] Pliny said that in buildings, besides the angles of walls and posts, also vaults (fornices) are to be considered as solid parts of the same. This probably is to be understood only for small vaults or arches, and, as he adds, for those which are well supported *(alterno pulsu renitentes)*.

which most abound. But in consideration of the great danger which occurs in certain districts, it will be advisable to have it modified, and if necessary to have it replaced by other kinds of construction of which we will speak afterwards.

NUMBERS OF STORIES AND MAXIMUM HEIGHT OF BUILDINGS.

Before going further with our subject, it will be necessary to treat an essential element of security, that is to say, that of the maximum height and therefore of the number of stories to be permitted in new houses. In every country subject to strong earthquakes, whenever it has been the question, either on the part of the Government or on that of the Municipalties, to make restrictive building regulations, in order to guarantee the security of people, the number of stories as well as the height of constructions over the soil have been limited. Of course such height can vary according to the different systems of construction, that is to say, it can be greater in timber, iron, or buildings of mixed construction and smaller in all those of simple masonry. A more or less heavy covering to the roof can also have an influence, as such a weight existing on the top of the building acts during shocks with considerable leverage. In a warm climate like that of Ischia, it will be difficult to avoid the use of tiles, which are very heavy, and to permanently replace the the same with metallic coverings of corrugated iron or zinc. On account of this it will be necessary to limit the height of buildings, which are not totally built of masonry. For those of simple masonry it will be wise in dangerous places to limit the same to only one not very high storey over the soil. Should other kinds of constructions, which will be afterwards describ-

[3] For the sake of curiosity we will cite a kind of monolithic construction, really remarkable for its solidity, and which has been employed in ancient times, but only for certain public buildings, as for instance for the basements of temples, and especially for wallings of towns and castles. These walls were constructed with large granite blocks or with other silicious stones without mortar. These stones under the influence of a great heat were partly fused and thus became united together. Such walls were covered with enormous piles of wood, the combustion of which produced the consolidation of the whole, thus forming an almost indestructible mass.

ed, be used, it will be possible to have much higher elevations without danger of destruction; but, on the other hand, various considerations suggest that it is not advisable to construct buildings of more than one ground storey. During strong earthquakes, terror and instinct urge the inmates to leave the house in any way. It is often the case, that people, who are in the upper stories prefer to jump into the roads, fearing that they may not have time to go down stairs, the staircase indeed being an obstacle for escaping. In almost all countries subject to strong earthquakes, the general custom and also the special building regulations prescribe either only a ground floor or not more than one storey. And without discussing this matter, considering that in Ischia the danger is very great, it is better to adopt such a rule, *viz*, that a building must have not more than two stories over the soil. It also being necessary to limit its height, we will, following the regulations of other countries which have been suggested by experience fix the maximum height at 10 mètres, or better at 9m. 50 over the soil, which is quite sufficient for all comfort and for internal accomodation.

In the meanwhile we must remember that the average cost of a dwelling house, having two stories and a cellar, and built according to the system used in Ischia, only with the substitution of ceilings for vaults, and having regard to the recommendations above mentioned, may be from 80 to 90 francs per covered square mètre, or 8 to 10 francs per cubic mètre of building over the soil. This price will serve for comparison with the other systems of construction which might be proposed.

### Iron Construction.

A building entirely of iron is from many points of view one of the most secure and durable. There is no doubt that the idea of metallic building gives us great confidence. But this kind of construction is not adapted to the conditions of Ischia. Its warm climate heated by an

almost burning sun, cannot fail to render such dwellings inconvenient. It is true that the transmission of heat may be diminished by means of coatings of other materials, as for instance by means of internal and external timber boards; but this would much complicate the construction and give rise to the inconveniences of wooden houses. The cost is besides much higher, at least for buildings of a certain importance; and would be certainly more than double that of masonry. But the greatest difficulty in this kind of construction is perhaps due to its being quite new to the island, on which there is no record of such structures. And there is no probability of seeing such radical changes in the habits of the inhabitants, who, having been accustomed to build their houses with the means at hand, will hardly adopt another system so very different from their own, necessitating the use of imported and very expensive materials.

Nevertheless, for certain small buildings, especially of a temporary character, and which if required, could be removed, some experiments could be made. All the necessary materials could probably be obtained in this case in the workshops of Naples or of the neighbouring places.

### Constructions entirely of Timber.

These are very safe even in the most dangerous districts, this material being well adapted to the formation of vertical frames for walls, roofs, and horizontal frames for floors. These frames may be formed by the union of triangles, a form which well resists stresses. By properly connecting the horizontal and vertical frames, a kind of cage equally strong under any strain may thus be obtained. Timber being rigid enough to resist shocks, as well as possessing a certain elasticity, which prevents it from breaking, it is therefore well adapted for the purpose we have in view. Besides, as it is a bad conductor of heat it is fitted for all climates. Examples of such structures, when timber is cheap, may be seen in many tropical regions. With this material double and treble partitions

with air spaces between, which is the best preservative against outside variations of temperature, may be easily constructed.

An example on a small scale, but nevertheless characteristic enough of the security of timber buildings, has been noticed in Casamicciola. This was the small theatre on the Bathing Square, which although very imperfectly constructed was an oasis of salvation to many people.

The defects, which are ascribed to timber, as for instance, its want of durability, the manner in which it is attacked by worms and other insects, its liability to fire, are now-a-days easily avoided. With regard to durability, if chestnut timber is used, of which floors and beams have always been made, we can under favourable conditions, calculate for one or two hundred years; a period that exceeds the requirements, which are now to be tried on Ischia. Such timber abounds, as we have already said, in the neighbouring southern provinces, and can be obtained of good dimensions and laid down in Ischia, perhaps cheaper than foreign fir timber; for instance beams of 8 mètres and more in length cost 85 to 90 francs per cubic mètre.

We now know how to provide against insects, even in timbers more subject to them than chestnut, by applying certain injections. Against the danger of fire there are different kinds of anti-igneous materials, with which the building can be painted and which do not prevent a later lime-coating on the same building. Many new preparations are known at present, as for instance in California and in Australia, by which the danger of fire is avoided and an almost stony appearance is given to external walls. By such means perfect security, cleanliness, and comfort can be obtained in timber buildings. Besides, if desired, we might construct, as in many Eastern countries, external and internal walls, not of boards but of trellis-work of small laths or of canes, covered with a good coat of lime, in which case buildings differ little with regard to

comfort, from those of masonry. But of this system, which may be very useful, we will speak later on. With reference to roofing, if it is required to obtain the greatest security, metallic coverings of zinc or corrugated iron, which are very light, may be used, or for constructions of less importance incombustible felt.

If we calculate the cost of a wooden house we shall see that on the average it is not higher than that of masonry as at present constructed; but for buildings made only of chestnut, with all the additions necessitated by the climate and other precautions, it would perhaps be for a house of two stories over the soil of from 110 to 120 francs per covered square mètre.

The actual temporary buildings, of which there exist more than 700, and which have been rapidly constructed, are of fir-boards, have only a story over the soil and are covered with corrugated iron. Each of these measures 8m. × 8m., or 64 square mètres, and has cost about 1,600 francs, or 25 francs per square mètre. This system, by means of which in the shortest time more than 9,000 persons have been sheltered, was adopted in consequence of urgent circumstances and because it was proportionally cheaper than others, which have been suggested chiefly by foreign builders of "chalets" who proposed to send the same ready made to Ischia. Several offers of such "chalets" have come from northern countries, but their price was exceedingly high. Very simple "chalets" did not cost less than from 100 to 150 francs, and with some ornaments in Swiss style from 250 to 300 francs per covered square mètre, without including the expenses for putting up the same on the spot. Farther, their erection ready for the inhabitants would not have been done sooner than the actual provisional buildings which have been constructed in groups and in different places according to the needs of the damaged localities; while on montainous parts the carrying of large and heavy pieces would have been almost impossible.

In conclusion, as to the admissibility of timber structures we have seen that the same offer the maximum of safety and can be made sufficiently durable, secure, and comfortable, although costing something more than ordinary buildings of masonry. The objection, however, is that the same ought to be constructed with imported material, which requires special preparation and attention in order to be used; while, as we shall see, there exist other systems equally safe and more adaptable to the character and conditions of the island.

### Mixed Construction of Iron and Timber.

In this system of construction vertical supports of the frames as well as a certain number of floor beams and other parts of the floor consist of simple and double *T* iron, the remaining parts and the walls being of timber.

Little has to be said of the mixed system which possesses the advantages as well as the disadvantages of the two kinds of constructions already mentioned. The same, therefore, does not offer particular advantages, with the exception perhaps of being adapted, when required, for the speedy replacement of damaged wooden portions, while the iron frame remains unchanged. It could be therefore occasionally used in some buildings, but we do not pretend that this should serve as a type to be imitated by the inhabitants.

### Mixed Constructions of Iron and Masonry.

Mixed constructions of iron and masonry, as well as those of timber and masonry, of which we shall speak later on, are various, but from a technical standpoint they may be divided into two rather different systems, that is to say:

(*a*) A frame-work of iron bars, covered with masonry, or, better still, completely buried in it;

(*b*) A metallic frame of vertical posts and horizontal beams well connected together by means of diagonal pieces, the whole

forming a kind of solid cage. The spaces between the posts, generally consisting of big double *T* irons, should be filled with hollow bricks or with other materials, well filled in between the beams so as to form solid walls. These walls might be made more or less thick according to the different sections of the iron posts, or, if required, by doubling the same, in which case we could have double walls with air spaces between so as to offer almost the same comforts as houses of masonry. The roof can be covered, as desired—for instance with tiles.

Such constructions are sometimes used in tropical colonies. In India we have many buildings of several stories, as military barracks, hospitals, and hotels, which have arrived from England quite ready, with the necessary number of hollow bricks, having therefore only to be put together on the spot.

Of course such constructors are solid enough even in countries subject to earthquakes, and they have the advantages of the so-called barrack system (barracat), of which we shall speak hereafter. It would be, however, convenient to limit the height of buildings, and besides to have the filling of masonry so fixed between the iron posts that during an earthquake it could not fall upon the inmates or on the roads. And this is not difficult to obtain, considering the forms which may be given to the irons in the frames, and the accessory means by which such walls may be protected, as by transverse pieces, net-work, etc.

This kind of construction can consequently be considered with regard to safety, comfort, and durability as adapted to countries with a warm climate and threatened by earthquakes, provided of course the same be applied by following all the necessary precautions to avert inconveniences. But in a place like the island of Ischia there will be always two principal difficulties opposed to the introduction of such a system. First, the cost, which according to the greater or less perfection in building may be from double to quadruple that of ordinary

constructions or also of others equally safe against destruction, but in which a material so expensive as iron is not used in such quantity. The second difficulty is of introducing its use among the inhabitants of Ischia. Therefore, such a system may be recommended for certain public buildings, to which a character of security and durabilities is to be given, and especially when the necessary expenseses can be defrayed.

The other kind of construction, that is to say, where we have masonry with an internal iron framework may be generally speaking acceptable, but with much reserve with regard to its method of application. Among the many proposals made to the Government for the reconstruction of Casamicciola there was one belonging to this system. It was proposed to make for every building a metal framework in the form of a cage which was to be coated with a special cement (calcestruzzo) formed from the broken *débris* of the destroyed houses mixed with good cement, the whole making a compact mass with metallic ties. However, there is a very serious objection against such kind of construction, viz., that this mass of special cement (calcestruzzo), although crossed by iron bars, would during shocks break and fall, and therefore, besides the danger of partial falling of masses, the building would lose its pretended monolithic advantages. Such a system would be less preferable than that above described. It would be perhaps better to use no "calcestruzzo," but ordinary masonry, especially if properly closed by partitions or by other means as in the former system. In Casamicciola (Genala's quarter) as an experiment, a small two-storied house according to this system, has been built, rails having been used instead of iron bars. It, however, cost very much; more than 150 francs per square mètre. With regard to its solidity, we cannot say anything, but must wait for a proper occasion.

### Masonry Constructions strengthened by Iron Keys and Bands.

The system of strengthening at different heights and

especially at the junction of the various stories and at the summit of masonry buildings, by means of keys, chains, or by iron bands, does, there is no doubt, add a certain cohesion to the various parts, which by themselves would have no other junction excepting that of the mortar. But by this system of binding together cohesion is only increased horizontally, it being purely of advantage during horizontal shocks (*terremoti ondulatori*). Vertically it can be of but little use, so that in case of strong and irregular vertical earthquakes (*moti sussultori*), which we have already unfortunately witnessed in Ischia, its efficaciousness would be doubtful. Nevertheless, such methods of strengthening is rather to be considered as an expedient to be employed for supporting buildings already damaged and in a dangerous condition, of which many are to be seen, rather than a real system of construction. In the province of Belluno, after the strong earthquake of 1873, a great many buildings have been strengthened in this way; but there was no question of introducing a kind of construction especially adapted to countries subject to earthquakes, and consequently this expedient was adopted. The use of iron keys and bands possesses the drawback of excessively weakening the points of masonry which they touch and where they act, accelerating therefore often the destruction instead af preventing the same, especially when the movements are very intense, as is the case during strong earthquakes. The examples we had in Casamicciola in certain buildings near the bathing places and in the already mentioned villa Di-Mayo, which has been completely destroyed, are of great importance. Should, however, such strengthenings be used, it would be necessary that at the points of junction with the masonry the stresses should be distributed over a great surface by means of large metallic plates or by a trellis of iron bars.

But in spite of all the precautions taken when using this system of metallic strengthenings, in case of strong earthquakes they cannot inspire much confidence, the building being

little else than an invertebral body subject to disconnection under the influence of shocks and especially so when they are vertical. We do not therefore consider it necessary to propose such a system.

System of Barrack Constructions (Case Baraccate).

The last system of building which we propose to examine chiefly consists in constructing, without taking into consideration the height over the soil of the building, a frame of timber beams, so disposed and joined together as to form a cage of an invariable form, whatever may be the direction of the forces acting upon it. And this is not difficult to obtain, when we join the various parts together by means of diagonals or crossing diagonals (*×croce di San Andrea*), and by properly disposed braces. The same should be done between the vertical beams of the wall and the horizontal timbers in the floors and trusses.

The vertical frames of this cage must then be, according to circumstances, so coated or filled as to close all spaces, in this way forming walls which may be internally and externally coated with an ordinary rough cast of good mortar out of which cornices and mouldings may be also made. By so doing, we obtain buildings resembling those of common masonry. There are two different manners of closing vertical and especially external walls. One of these, which is relatively very light, has been used from remote times in different parts of the Levant, especially in those districts subject to earthquakes. It consists in applying to the two faces of the wall a trellis work of small wooden boards, or of canes nailed on the frame-work, which are then covered with mortar. In the wall there is therefore an air space, which is a very good medium for moderating the difference between the internal and the external temperature.[3]

[3] An analogous but an improved system of construction, has been proposed as a type of security by Inspector Comotto. It is described

The other system, which although heavier is very much used even in warm countries, where light stones, as for instance certain kinds of scoria, abound, or where hollow bricks may be cheaply procured. It consists in filling the spaces in the frames with such materials, especially on the outsides projecting over the beams, thus giving to the external walls a certain thickness, for instance of 0.25m. and 0.30m. This thickness protects buildings from fluctuations in temperature just as ordinary walls do. It is understood that even these walls must be externally and internally coated with good mortar rough-cast and mouldings, so as to have the appearance of ordinary masonry.

With regard to floors, they can be made of good boards nailed on the floor-beams. On these boards a thin layer of mortar is laid which cements together and attaches to the planking a floor of small square stones or bricks, as in ordinary pavements. Ceilings and internal partitious may be coated with mortar and even ornamented with attached mouldings, which at present are made of a very light material. For roofs several kinds of coverings may be used; but in consideration of the safety which these buildings present, tiles or terraces may be adopted without any serious danger; an advantage which, in a warm climate and in consideration of the customs of the inhabitants, is not to be overlooked.

As we shall mention hereafter, buildings of this system with walls filled with stony materials, have been for a long time constructed not only in several foreign countries, but also in Italy, viz., in Calabria, in the Benevento province, and in Norcia (Umbria), all of which are places which have suffered from strong earthquakes. They have been called "*case baraccate*" and hence our name for this system. Strictly speaking, this kind of construction does not differ from that of iron

in one of the pamphlets regarding new buildings for Ischia, which has been published by the Civil Engineers Petra di Caccuri and Mesingher of Naples, and recently forwarded to the Department of Public Works.

and masonry already described, the only difference being that in the latter the frame is of iron while in the former it is of timber. It is of course necessary to fix the filling material so that it can not fall at the time of shocks. This can be done in several ways, as for instance by making cuttings in the beams and by cross-pieces in the walls, so that the filling has a support, or by means of net-work, etc.

Considering the certain degree of elasticity of wood, timber frames present sufficient security. The size of the timbers employed, which will commonly not be less than 0.15m. or 0.20m., is not only sufficiently strong, but very convenient for securing the parts together and for forming a good support to the filling materials. And it must be noted, that according to a long experience, if a building has a cellar this may be constructed with common masonry and not "*baraccato*," it being sufficient to employ this system for stories over the soil. In this case, in order to obtain greater security, beginning by constructing a general basement of good beams on which the cage or frame of the building is strongly attached.

After having spoken of the peculiarities of this kind of construction, it is hardly necessary to notice that the same is not to be confounded with that of the thin walls, called by the French "*pan-de-bois*," which is sometimes used on account of its cheapness. In these walls the wooden frames are visible. And especially it must not be confounded with the system used in certain buildings of masonry, where, in order to give a greater resistance to the walls, simple timbers, which serve as ties and internal bands, are buried. It seems that these timbers, when buried, do not last long, and usually do not add great strength to buildings, but often weaken walls of masonry.

The barrack system is, as is easily to be seen, quite different, because the timber used in it is not employed as a simple strengthening material, but as the principal factor.

With regard to objections which might be made against

timber for such important use in barrack buildings, as for instance those of durability or of danger, and of destruction by worms or fire, the reply is simple, although that deduced from long experience ought to suffice. Durability depends upon the quality of timber used. In many countries we find fir-timber, especially red-fir, used, while in others chestnut or oak is employed. The two last are used chiefly because they are found in the country. In Ischia chestnut, which as we have already seen, can be economically procured, and which may last more than one hundred years, may be employed. The danger of worms may be prevented by means of injections and that of fire by anti-igneous preparations, although the external roughcast renders the latter precaution superfluous. The difficulty, which has sometimes been mentioned of making the roughcast adhere to the timber, is easily accomplished, by means of cuttings in the timber and the heads of nails made to project over the same. But in consideration of the great and essential advantage of this system, which had its origin in countries suffering from earthquakes, and in view also of the maximum security it presents against seismical motions, it is hardly necessary to discuss farther such trifling objections.

We believe that, considering earthquakes, and on account of the sanction this system has obtained after long experience, it will be useful to cite examples from several countries whence it originated.

The most interesting, although not the most ancient case, is that of Lisbon after the terrible earthquake of 1755, which destroyed a great part of that city. The Marquis of Pombal, who was at that time Minister of State, caused a Royal decree to be promulgated, regulating the reconstruction of the city, especially its lower part along the river Tagus. The barrack system was imposed. This consisted of a cage (gaiola) made of timber beams so constructed as to be easily filled up with a coherent material, and limiting the number of stories over the soil to two. These regulations were so severe that a house,

which was found to have been differently built, had at once to be demolished at the expense of its owner. Besides, the ground in the lower part of the city being muddy, it was necessary to build upon deep piles covered with cement (calcestruzzo). On the hills the foundations of buildings were constructed upon a solid soil, with which they were strongly connected. The timber which they used was fir imported from North Europe, a very lasting material. This new system of construction became customary, and people had such confidence in it, that now though the severity of the law has relaxed, barrack-palaces of 4 and 5 stories are built. It is true, that although earthquakes are frequent there, no successive commotions ever reached the force of that of 1755. In 1858 a strong shock was felt, which destroyed a part of the suburbs of Setubal, but without damaging the city. An interesting peculiarity of the houses of Lisbon is their external coating, generally made of nice little enamelled squares, which form decorative artistic ornaments. It is an excellent protection against the sun, and at the same time its appearance is gay, clean, and decorous. Such kind of buildings might be adapted for a new Casamicciola, while the use of enamelled squares, which are manufactured at Naples, would benefit a local industry.

Other countries subject to earthquakes are Japan, lower Chili, several parts of Java, Asia Minor, and, without looking for other regions, the different places in Italy, which we have above mentioned.[4]

We could say very much more on this subject, but for the sake of brevity, we shall confine ourselves to a few citations.

In Japan houses were up to recent times entirely of timber, bamboo being sometimes used, and they usually only rested

[4] During the strong earthquakes of 1881, which were experienced in Scio and in its surroundings (Asia Minor), almost all the houses built of common masonry, some of which dated from the times of the Genoese rule, fell, while in other nearer places buildings constructed after the barrack system, as used in Smyrna and in other localities of Levant, resisted destruction.

upon the soil. But the frequency of fire led afterwards to the system of barrack-masonry, which was used for new buildings, and it is in such a manner that certain public fire-proof go-downs have been constructed. They are externally covered with a well polished strong roughcast, in order to protect them from the flames. The Italian Legation in Yedo consists of several buildings, for the use of the officials and servants, constructed according to the Japanese system, but more or less modified. However, the central small house, which has been especially built for the Minister, has only a low story with walls of granite and bricks. It is constructed according to the barrack system and has timber posts, well founded on the stones which support the roof. In the same way a polygonal chapel for religious services has been built.

In lower Chili, which is subject to very strong earthquakes, it is the custom to construct only one storied buildings, of only a ground story, and this according to the barrack system.

The bricks, which serve to fill the walls, possess cuttings, in order that they become well attached to the transverse pieces in the walls, and consequently they are prevented from falling.

In Lima some masonry buildings exist which are very strongly constructed, and which have resisted various earthquakes. The houses, however, have generally only the ground story of masonry, and if another one has to be added, this is done with very light timber; an easy matter, as it never rains there, and the houses have no roof.

Several other examples of eastern European countries and of Asia Minor could be quoted, where the barrack-system, chiefly with walls of trellis-work, is employed. The same being very light, it is permissible to construct more than two stories. In the barrack-system, however, with walls covered with solid materials, which for several reasons are to be preferred, it is necessary to limit buildings to only two stories. Cosenza in Calabria, and Benevento and Norcia in Umbria offer us examples.

In Calabria the owner of a barrack-house, in letting it, arranges with the lessee that in case of danger he (the lessee) must lodge him and his family, during the days on which there are earthquakes, in a part of the same house;[5] this proves the confidence the people have in that system. Other owners of houses, which do not belong to the barrack-system, used to build a special earthquake-proof room, with an internal frame of iron bars, in which they could take refuge with their family.[6]

In Norcia, a city subject to strong earthquakes, the municipality after the seismic commotion of 1859, which destroyed the town, compiled building regulations, which were approved by the Pope's Government and put into force in April, 1860. According to these, vaults are abolished, the height of buildings is limited to two stories over the ground and other obligations are imposed, a good deal of which could be copied for Ischia.[7]

It seems now to us that it is unnecessary to discuss other arguments and to quote more examples, and therefore we conclude by proposing such barrack-system as the type to be adopted in localities threatened by earthquakes. As we have already said, iron constructions and frames can be equally included in the barrack-system, but they are expensive and not adapted to local conditions, while buildings with timber frames (chestnut for example) are not only equally safe but much cheaper, and will not present any difficulty in being introduced in Ischia.

With regard to expense, after due calculation it seems that the cost of a barrack-house built with good chestnut

[5] Mr. E. Artom, Inspector of Civil Engineering, who has lived in Cosenza, gave us the example of a similar agreement between an owner of a barrack-building with the lessee Rizzo, in which it was also said, that of such an obligation due account has been taken in fixing the rent.

[6] There exists a short pamphlet of a certain Engineer P. regarding the barrack houses of Calabria, which also mentions the earthquake-proof room and gives its plan.

[7] See Regulations for Norcia of 1860 in the supplement to this report.

timber and well constructed in every part, covered with roof or terrace, will not much exceed that of a building of ordinary construction, viz., if of two stories over the soil and with a cellar, 95 francs per covered square mètre, or less than 11 francs per cubic mètre.

This system might be used for public buildings, as for Government and Communal houses, as well as for hotels and theatres, selecting for the most important buildings convenient proportions and forms, in order to lessen the dangers.

### Conclusions about Rules to be fixed for new Public Buildings and prohibitive Regulations for Private Constructions.[8]

The rules, which the Committee desires to propose in fulfilment of its task, are deduced from all that has been said in the preceding chapters, especially in that relating to the curious zones of soil more or less dangerous, and in the other referring to the different systems of constructions to be adopted.

They must point out the type best adapted for public and private buildings in those communes of the island which are threatened by earthquakes, and at the same time the prohibitive regulations which it might be found necessary to impose on private constructions in the same communes.

In countries which have suffered strong earthquakes, the sad effects of which have been very often increased by bad systems of construction, with the object of obtaining security for the people, has compelled Governments and Municipalties to formulate more or less severe rules, which have been inserted into special building regulations, examples of which we have mentioned, as for instance Lisbon, Benevento, and Norcia.[9]

[8] With regard to the conclusions of the Committee, especially on the system of construction to be preferred, one of the members reserved his opinion; nevertheless in the compilation of the instructions A and B, as far as possible advantage has been taken of his co-operation.

[9] It seems that formerly similar regulations have been published in Ischia, but they could not be found, and it does not appear that they have ever been enforced.

Such regulations show and order, according to circumstances, the type of houses or of other buildings, and give rules for their good construction. They contain also, the above mentioned prohibitive rules, which are compiled more especially with the object of avoiding dangers to human life.

For the carrying out of such regulations in the present case a special office of management and supervision composed of competent persons would be required, who could reside on the island or at least keep an agent there. After having established for a given commune a plan for the new quarters, all projects of public and private buildings of a certain importance ought to obtain sanction from such an office, which would have then to look after their execution and care for all the other particulars relating to the matter of building, which are peculiar to such commune. After having mentioned the necessity of such measures, we will not enter into particulars, which may be dealt with by the administration.

Coming to the practical points, for a moment we will pass by the discussion of the new plans of quarters of which we shall treat hereafter, and at once take up the building regulations, of which at least the technical basis must be established, whilst their definite form, where legal or administrative questions are concerned, must be made with the cöoperation of persons conversant with such matters.

As the rules and prescriptions which will be mentioned contain numerous and detailed particulars, it will make this work to give here the motives which lead to them. We therefore consider it better to omit the same, it being quite sufficient to refer to what has been already mentioned in the different chapters of this rather too long report. We therefore present the relative instructions, which have already been framed under the form of articles, dividing the same into the two following parts, A and B.

The first part, A, contains the rules for the construction of

public buildings, and the second part, B, the rules relating to private buildings.

The rules A, which should serve as a basis for the construction of government, provincial, and commercial buildings, might also serve as a type to be imitated by private people, without enforcing them on the same. The second part, B, contains only compulsory and prohibitive rules with respect to security, which can and must be imposed on private persons. Among these, special attention must be given to those concerning buildings already existing, which are more or less damaged and require to be repaired, rules which may present even some legal difficulties. Take for instance the case of vaults of masonry; the same being prohibited in new buildings, their demolition should be ordered. But can this be done if there is no evident danger or at least without indemnifying the house owner? In view of such difficulties which might arise, we have believed it better to limit our proposals of restrictive measures to the minimum.

It may be observed that the proposals which have been made, and especially those for public buildings, are rather severe, as for instance in the almost general exclusion of ordinary masonry without frame-work; but in consideration of the admitted possibility of new and strong earthquakes, the responsibility of the Government is great, and in such case many precautions must be taken. By the new system of construction no heavy charges are imposed on citizens, the buildings being not much more expensive than the present system. Besides it is necessary to be severe, in view also of the usual slackness which after a certain time begins to prevail in the observance of compulsory rules. Future experience, even about the course of seismic phenomena in the island, may perhaps suggest some modification of what will be now established.

In order to inculcate the established rules, the Government itself, besides creating the already mentioned office of manage-

ment and supervision, and taking care that proper building regulations are published, should give a good example, by strictly adopting in buildings which it has to construct on its own account jointly with the province and communes, the rules ordered in instruction A. In private buildings, it might use a certain influence and facilitate matters by means of a collection of proper drawings and models for new types of construction. It would be good to exhibit among these types, examples from some of those countries which may be considered classic in this system, as for instance Lisbon, where there exist types of houses which on account of the enamelled material by which they are covered have a beautiful appearance.

Should, however, circumstances require, and in order to avoid difficulties and monopolies, some warehouse for good timber at reasonable prices as well as mortar and other materials, which are not to be found on the island, might be established in Ischia.

But the Government, or those who will dispose of the money generously subscribed by the public, can exert the greatest influence by distributing subsidies, preferably, or at least on a larger scale, to intelligent and willing people, who would take the initiative in adopting the new styles mentioned in the instructions A and B.

### A.—Building Regulations proposed for new Public Constructions in those parts of Ischia threatened by Earthquakes.

1.—New buildings, whatever may be the system of construction adopted, ought by preference to be erected on the least dangerous sites, as on plains, and avoiding the hills. Should this be impossible, ground with little inclination, far away from ravines and where the arrangement of the strata is not favourable to dislocations, must be selected. Under all circumstances an excavation in order to remove disintegrated materials

and soil must be made; this must be dug until a solid natural ground for the foundations has been met.

2.—Should the locality allow, new buildings must be constructed on solid lava or on well connected and united volcanic tuff; this being preferable to ordinary tuff, clay, and other less consistent material.

3.—Whenever the ground, either on account of its nature or in consequence of faulty stratification, does not offer, in spite of the excavations, sufficient solidity, the building should be placed upon a general platform of masonry or of cement (calcestruzzo), which must have, in case of one-storied buildings or of constructions of light materials, a thickness of not less than 0.70m. and of 1.20m. if the building has more than one story, and is altogether or partly constructed of masonry.

If the building has no cellar but only a foundation resting on the soil or a little over the same, this must, according to the project, extend 1m. to 1m. 50 over the base of the building.

4.—With regard to security, different parts of the ground, some of which are more and some less dangerous, must be distinguished. Among the former are localities which are near to the centres of commotion (as for example the higher part of Casamicciola under Mount Cito, the valley where there are baths, etc.). There is also ground which on account of its nature or of its steepness offers considerable stability, as, for instance the hills of Casamicciola from the foot of Mount Epomeo to the sea-shore. Places which should be abandoned, or for which at least severer rules are necessary, must be indicated on a special plan, and in particular cases they may be pointed out by the technical survey office of the island.

5.—Among the second zones, besides the above mentioned districts of lava and solid tuff, we have the sea-shore, where buildings have only suffered moderably during the last earthquakes. In selecting localities near the sea, it will be convenient to take those which are above the ordinary level. This

is done in order to obtain protection from disturbances in the sea, which might sometimes accompany great motions of the earth.

6.—The plan of buildings of a certain importance, especially of those having more than one storey over the soil, must be square or nearly square in form.

7.—In places where a predominant direction for earthquakes has been ascertained, one of the diagonals of the plan, ought to be in such a direction.

New buildings, whatever may be their system of construction must not have more than two stories over the soil. They may have in addition a subterranean cellar if it is required.

The height of the subterranean cellars must be strictly limited to the requirements, and the total height of the two stories over the soil, from the lowest point of the soil to the summit of the external walls, must not exceed 9m.5.

As a rule for new buildings of a permanent character, whether these are of one or of two stories over the soil, the so-called barrack system, with timber or iron frames, according to circumstances, so arranged as to solidly connect the frames of the floors with the truss of the roof, must be adopted.

The filling of the wall frames may be made in different ways, according to the best system of the district where such kind of barrack constructions are used, but preferably with materials such as are used in Calabria and in other parts of Italy. The materials must be as light as possible, and must be arranged in such a manner as to prevent their falling during earthquakes.

For provisional buildings or for those which have to be constructed with but little delay, and in dangerous places, constructions made entirely of timber may be adopted. These are to be executed according to the rules, which will be hereafter mentioned.

If such buildings have to serve for a long time as dwellings,

offices, or for similar use, their walls must be internally and externally coated with a good roughcast of lime and puzzolana or with other convenient cements properly applied to the trellis or boards. This is for the sake of cleanliness and protection against fire.

Hearths, chimneys, pipes, gutters, and closet tubes, must be isolated from the walls. If such buildings have two stories, their roof must be, as a rule, covered with light materials, as zinc or corrugated iron, and temporary buildings with impermeable and incombustible felt.

For buildings of only one storey over the soil, which are not used for dwellings, or which are situated in less dangerous places, walls of simple masonry may be also adopted, provided they are constructed according to the rules, and in their upper part they should be well connected together and with the roof by means of external and internal supports.

If in dangerous regions it is necessary to have another story over a ground storey of already existing common masonry, such a story might be constructed, provided it be entirely built of timber and according to the lightest system, and ceilings may be added to the vaults of the ground storey, provided the stability of the walls of the same is good.

In new buildings, vaults and floors of masonry in stories above the soil are prohibited. They are admitted underground on the condition that they be constructed with good materials and with good mortar, that they be unicentric, with a sine not less than $\frac{1}{3}$ of the chord, and at the crown of a thickness not less than cm.23.

Buildings having walls of brick or of stone, without frames, may be constructed.

Bricks are to be preferred, but if local tufaceous stones are used they must be cut in parallelopiped form and in pieces of a length, sufficient to have the walls strong and well connected together.

Masonry of round or irregular materials or having an empty space for the filling (à sacco) are prohibited.

Mortar must be composed of lime and pure sand, or of lime and good puzzolana of Naples or of Ischia, carefully excluding any admixture of earth.

The thickness of the walls must be in proportion to the height, but as a rule, $\frac{1}{3}$ to $\frac{1}{2}$ greater than that commonly used. In buildings having only a ground floor, the internal height cannot exceed four mètres, and the thickness of the external walls, if they are constructed with local tufaceous stones, must be at least om.70. If brickwork, which is known to be excellent for countries subject to earthquakes, is used, the thickness may be somewhat reduced.

When there are walls of common materials, the openings of windows and doors must be made perpendicularly over each other, and in external walls they must not be at a less distance than 1m.50 from the corners. These spans, instead of being made by flat bands, must be covered by a solid architrave or by an arch of good material, having a sine at least equal to $\frac{1}{3}$ of the chord. In this last case the inferior face may if necessary be levelled, by means of solid timber or iron beams well let in to the sidewalls, which support the light boards closing the segment.

It is prohibited to leave in the thickness of walls chimneys or cavities with or without conducting pipes.

As a rule it is also prohibited to make any projection or abrupt irregularity of construction, with the exception of iron or timber balconies provided they are solidly constructed so as to form a part of the wall, which at their outmost point must not project more than om.60.

In buildings solidly constructed and especially in those of one story, roofing may be for the sake of comfort covered with tiles. These, however, must be light and made so that they may be fixed on the truss by means of nails, hooks, or by other means, in order to present their falling should violent shocks occur.

In other cases a covering of flat zinc plates with freedom for expansion, or of corrugated iron must be adopted, taking precautions necessary to lessen the easy transmission of external heat.

Whenever by special reasons it is necessary, buildings may be covered with terraces, but those of small stones (lapillo) set on a layer of very heavy masonry are not allowed. Instead of this layer a thin stratum of mortar made of puzzolana, resting upon a strong floor of chestnut, and then a layer of asphalt, upon which comes another of mortar and finally a pavement of well joined bricks must be used.

The filling of masonry for external as well as for principal internal walls of buildings, constructed according to the barrack system, must be of the lightest materials, such as hollow bricks or scoriaceous stones, which abound in the island, and must be well kept together, either by means of cavities expressly made in the walls, or by a trellis of timber or of metallic wire, or by other means, in order that it may not fall either inside or outside of the wall.

These external walls must, for protection against change of temperature, contain a thickness of at least om.30 of such material, which, as has been described, must be placed tightly together.

Churches which may be constructed, must be of moderate size, it being much better to build several small churches than a very large one.

The Basilica form with three aisles, the side aisles of which may be very high, is preferable.

The system of construction of the walls, which is to be preferred, is the "baraccato" with iron or timber frames, but in such case the columns between the naves must be of iron.

Bells must not be suspended from isolated and very elevated towers, but at a height little over the walls of the church, or from small towers formed by the same walls, or from some of

the most solid church walls and far away from frequented places.

The walls of support for farming grounds or those for the separation of properties along public roads, must be constructed, according to technical rules, of materials well cut or at least of roughly made parallelopipeds. The thickness of these walls must be somewhat greater than that of ordinary walls, and with more or less escarpment, taking, however, into consideration the predominant directions of the shocks.

As there exist in the island many mule paths closed by small dry walls with but little solidity, which during earthquakes fall, causing danger to people and destroying the means of communication, the respective municipalities must be invited to look to those whom it concerns, and so far as possible remove such dangers and nuisances.

### Accessory Articles concerning different Details of Construction.

In barrack-buildings having timber or iron frames, and especially in those of two stories, in the frames of walls, between the beams of floors, and in trusses, a sufficient number of diagonal pieces for the formation of triangles, which secure the rigidity of vertical and horizontal joints as well that of the vertical and horizontal parts, must be used.

The spans between the pieces of wall-frames of timber buildings, especially in the ground floor, must as a rule be so narrow that they will not allow a person to pass through.

For the support of roofs the system of simple beams following the inclination of the roof or resting upon posts or walls is prohibited, but complete trusses, the horizontal beam of which will at least reach to the external facing of the walls and will lie on another beam resting longitudinally upon the same walls, must be used.

The whole must be properly connected so as to form a rigid system, able to resist shocks in various directions.

Vaults, as coverings for habitable rooms, being abolished, only ceilings of solid and well joined beams are admitted. Upon these beams the floor planks, arranged if possible diagonally, are nailed.

The pavements on the ground storey as well as those of the upper storey, must consist of enamelled squares or of other common material.

When the ceilings are coated, the roughcast, which is applied upon a strong trellis, must be of good mortar, thin, and without any embossed ornament likely to fall. For this purpose connected pieces of a light material are used.

Should it be necessary to execute repairs and consolidate walls in old buildings by means of iron anchors and bands, these must act upon a great surface of the walls. This may be accomplished by means of large metallic plates, by iron nets, or by long bars.

The timber to be used for the frames of walls, for the beams of ceilings and floors, casing, planking, etc., must be of chestnut, well cut and preserved. For greater precaution the same may be preserved from worms and other insects by injections. Secondary frames may exceptionally be made of other timbers, but properly prepared.

In the parts which are subject to fire, the timber must be several times coated with some incombustible preparation recognized as being efficacious.

### B.—Rules for Private Buildings.

It is prohibited in localities belonging to communes, which have been damaged by earthquakes, to construct new buildings or to repair the damaged ones without a permit from the office for supervision of buildings, which will be delivered upon application. In such application the locality of the proposed works must be indicated. If the building is intended to be of a certain importance, and especially if it is to have two stories

above the soil, the said application must be accompanied by sufficient drawings, to give a clear idea of what it is proposed to execute.

Should a building plan be accepted, the situation of the new building must be fixed according to this plan by the same office.

To the permit a printed copy of the special public and private building regulations for Ischia must be annexed gratis.

In new constructions the best technical rules must be followed. The rules contained in the said Regulations must be generally observed and especially the following ones :—

It is prohibited to construct buildings of masonry on the steep side of hills or upon sloping soil, although supported by walls, unless after a convenient excavation the solid ground has been reached, upon which the foundations must be laid. In case of important buildings or under special conditions of ground, a platform might be required.

Buildings used for dwellings or meeting places and especially hotels, coffee-houses, places of amusement (ridotti), etc., must not have more than two stories over the soil, and their total height from the lowest point of the soil to the summit of the external walls, must not exceed 9m. 50.

Under the two mentioned stories a subterranean cellar of a height limited to the requirements may be constructed.

In dangerous zones and generally on very sloping grounds, dwelling-houses of one or two stories over the soil, should they not be made entirely of timber, must be constructed according to the system of barrack-houses with wooden or iron frames. Similar constructions must be properly strengthened by diagonals so as to resist without variation shocks in different directions.

Walls may be either lined with stone, as in Calabria, or only internally and externally covered with small boards or lathing coated with a good roughcast.

If a construction entirely of timber or of iron is not adopted, the said system must, in all localites of the threatened com-

munes, be used, that is to say,.for all buildings, either of one or of two stories, used as hotels, bathing houses, theatres, places of amusement (ridotti), and others in which many people congregate together.

In such buildings doors and principal stairs must be so arranged as to allow a quick escape in case of alarm.

In less dangerous zones, buildings used for private dwellings may have walls of simple masonry over the soil, provided they are limited to one storey besides the cellar.

The walls must be constructed according to the rules, and well bound together, and in their upper parts must be connected with the truss or with the framework of the roof which carries the terrace, by means of internal and external supports.

When the foundation can be laid upon consistent ground, as for instance upon solid lava or volcanic tuff, masonry may be allowed even for the first storey, but with the already mentioned precautions as to solidity.

Vaults of masonry in stories over the soil of new buildings are prohibited. Vaults are only permitted in cellars, provided they are made with good material and with good mortar, they must be unicentric, and with a sine not inferior to the third of the chord, and, if made of tuffaceous stone, they must have a key at least om.25 thick.

In wall constructions the use of round or irregular stones, as well as of hollow masonry with filling is prohibited. Stones must be at least roughly dressed and reduced into parallelopids with a face of such a length as to allow them to be well connected, especially near the corners and the openings, as well as at the junctions with the partition walls.

Mortar must be composed of lime and pure sand, or of puzzolano sand excluding all admixture of earth.

Small walls of support or separation, which are constructed on public roadways must both in the country and in inhabited districts, be built according to technical rules, in order that

they may not become a danger and a nuisance to roads in case of earthquakes.

The construction of the same with irregular or with dry stones is prohibited unless their solidity is secured by a sufficient escarpment without inconvenience to public traffic.

In case of dwellings of common masonry, the openings of windows and doors must be vertically over each other, and at a distance of at least 1m.50 from the corners. Over the said openings solid architraves or small arches having a sine not inless than the third of the chord must be constructed, leveling in such case, if necessary, the inferior face of the span by means of solid iron or wooden planks let well into the side walls; these may support the centering of the arch made of light b oards.

In buildings of only one storey over the soil, the external walls, if they are constructed of local tufaceous stone, must have a thickness of at least 0m.70, and in case of two stories such thickness must at the ground floor be at least 0m.80. The external walling of the first storey may be dimished to 0m.15.

If brickwork, which has been recognised to be excellent in countries subject to earthquakes, be used, the thickness may be somewhat reduced.

It is prohibited to leave in such thickness of walls, chimney flues and openings, either with or without pipe linings.

As a rule, every projecting or abrupt change in construction is prohibited, with the exception only of balconies, provided they do not project more than 0m.60 over the road. These should be of timber or of iron, and be solidly constructed so as to form a part of the same wall.

In buildings constructed after the barrack system with iron or timber frames, the filling material of the external and internal walls, be they of stone or of bricks, must be as light as possible, and prevented by means of notchings, transverse

pieces, or metallic net-work, from falling during earthquakes either in or outside the walls.

Should tiles be used for covering roofs, these must be light, especially in the case of a building of two stories over the soil, and well fastened by nails, hooks, or by other means, to prevent them from falling during earthquakes. Under the roof a good planking nailed on the beams supporting the ceiling must be put for protection of the rooms underneath.

As a support for roofs, the system of simple beams, following the inclination of the roof resting on posts or on walls is prohibited; complete trusses, with horizontal beams prolonged at least as far as the external face of the walls and bearing upon another beam put longitudinally on the same walls, must be adopted.

The whole must be properly connected together, so as to form a rigid system which can resist shocks in various directions.

In the case of solid terrace coverings, as they are used in the island, they must rest on a strong planking of chestnut nailed upon the supporting beams. These beams must bear with their whole thickness upon the walls, and if necessary be strengthened underneath by two or more beams running at right angles.

The same rule for bonding into the walls, must be followed for ceiling-beams at the different stories, in order that the whole may be properly connected.

The timber to be used in new constructions must be of good quality and well seasoned, preferably chestnut, or other timber properly prepared to resist worms or other insects.

In the parts exposed to fire and especially in wooden buildings, the timber must be several times coated with some incombustible preparation, recognized as efficacious.

### Special Rules for repairing damaged Buildings.

After a notice given by the Office of Supervision established

in Ischia, a total or partial demolition of such buildings might be immediately ordered, as, either on account of the damage they had suffered by earthquakes, or by the yielding of the soil or inundations, or by any other cause of decay, might present danger of destruction.

The third story of the damaged houses must be demolished rather than repaired, should the repairs involve considerable expense.

After a notice from the same office, the vaults existing on the second and first stories over the ground story must be demolished and replaced by properly constructed ceilings.

Vaults on the ground storey may be preserved provided they are in good condition, but they must be strengthened by iron chains and bands, and, if necessary, be made lighter.

Should a ceiling which supports a terrace not present sufficient strength with respect to the weight it bears, on account of the heavy stones and *terrazzo* which serve as a pavement, it must be demolished and reconstructed, according to the above-mentioned rules. In case of smaller danger it will suffice if the weight be lessened, replacing the *terrazzo* or stones by a pavement of small squares resting upon a light layer of mortar and asphalt.

If it be necessary to consolidate walls and vaults by means of iron bolts and bands, these must act over a great surface of the walls by means of large metallic plates, or net-work or of long thin bars.

In cases where either the danger is not severe or the expenses of the total reconstruction of a house are too heavy, it may be permitted for the owner to reconstruct according to the barrack-system, only a special part of it, where his family or the inmates might find a refuge in case of danger.

Rome, November, 1883.

(Signed) F. GIORDANO.
P. COMOTTO.