Materials and construction procedures in the region affected by the earthquake of November 10, 1922.

By

EDUARDO AGUIRRE

Annals of the Chilean Institute of Engineers

(n°5) May 1923

Transcript C. Vigny 13/2/2024[1]

[1] *Nb: Since the digitization of the document has considerably degraded the quality of the photographs, they are not reproduced here.*

I. - INTRODUCTION

On November 23rd of last year I went to the province of Atacama to carry out the commission that had just been entrusted to me on the effects of the last earthquake in the different constructions of the devastated area. The time available to me for this purpose was short, due to the need to return to attend to some unpostponable obligations in Santiago. However, and thanks to the fact that it was possible for me to have the indispensable means of transportation available with more or less opportunity, and also to the fact that the construction systems used in the region were of a great uniformity, I was able to realize the main causes of the damages observed in the seven cities that I visited in a tour that lasted nineteen days.

In this report, apart from the matter proper to the commission, I will refer in passing to some problems derived from the situation created by the earthquake, and in order to give a more complete idea of the whole, I will also say a few words about the phenomenon itself and the outflows of the sea that followed.

The numerous accompanying photographs, some of which were acquired commercially from among those taken immediately after the catastrophe occurred, the others taken later by me and by other engineers in charge of studying the reconstruction of the devastated cities, contribute to illustrate the present information. For the same purpose, four small plans and several diagrams and sketches are included.

II. - EARTHQUAKE AND SEA DISTURBANCES

I do not know the report made by the Direction of the Seismological Service on the characteristics of the earthquake of November 10. It seems that the most accurate version based on observations made in the field of the catastrophe is that of the Professor of the Copiapo High School, Mr. Luis Sierra, who is in charge of the Seismological Station of that city. Accustomed to make this kind of observations, Mr. Sierra wrote down in his notebook the characteristics of the tremor in the best way that the critical circumstances of the moment allowed him. The recording devices were put out of service as soon as the movement intensified. The following list has been made with the data of the aforementioned professor.

The main oscillations were from northeast to southwest, accompanied by horizontal oscillations in different directions and some minor vertical oscillations. The phenomenon began at 23h53'30", with an intensity of 5° of the Rossi-Forel scale; it remained 30" in this state, and then increased to the eighth degree, in which it delayed 20" violence with which the clocks stopped. It passed at once to the maximum degree, tenth of the mentioned scale; it remained in it for 3' and it diminished later to third and fourth degrees, intensity that was maintained until 0h4' of the 11th, hour in which again it increased to eighth degree, to reduce itself definitively. The total duration of the earthquake was 11'.

It should be noted here that the intensities of the practical seismometric scales in use have relative values, since they are based on the disturbances produced by the tremors in ordinary life and on the damage caused to buildings. The X degree, maximum of the Rossi-Forel scale corresponds to a movement qualified as disastrous, that produces the total or almost total ruin of several houses, serious injuries in many others and some human victims distributed in diverse inhabited points. With such a criterion, it is understood that, in an area of poor construction, an earthquake will always be attributed a higher intensity than that assigned to it in another region of better construction.

In Vallenar the tremor was felt at 23h53'20", as verified by an

employee of the Copiapo telegraph who communicated with Vallenar and who received the announcement of the movement before the slightest oscillation was noticed in Copiapo.

Mr. Sierra also provided me with the following data on the atmospheric conditions that night. Before the tremor, the sky was 2/10 hazy. Immediately after the occurrence of the phenomenon, there was drizzle, and half an hour later, the clouds completely overcast the sky. During the main phase of the phenomenon, several lightning flashes were observed on the horizon. It should be noted that in Copiapo there were no fires and that the electric power plant stopped working with the first aftershocks, due to the obstruction of the turbine channel.

The Maritime Governor of Caldera, Lieutenant Commander M. A. Rojas, in a communication to the Directorate of the Navy, confirms Mr. Sierra's version of the atmospheric conditions on the night of the earthquake, and adds that the weather was very variable in the first fortnight of November and that after the 10th, disturbances were noted in the tidal regime.

The employees of the Coquimbo shelter assured me that before the seismic event the night was relatively clear, that after 24 hours it became cloudy, that then lightning was observed on the horizon and that after 2:00 a.m. on the 11th there was drizzle.

News from the other cities visited about these ports is vague, but they agree that the night was dark and the weather variable.

It was curious to note that many neighbors of a certain education, related the events, not as they occurred, but as they believed they would occur according to the knowledge they possessed, acquired in high schools or in later readings This was especially true in the case of the departures from the sea.

The area of greatest violence seems to have been the Huasco Valley, due to the greater destruction in the constructions of Vallenar, Freirina and Huasco Bajo compared to those of Copiapó.

Of the ports that suffered from the tsunami, I visited Chañaral, Caldera, Huasco and Coquimbo.

I heard innumerable accounts of the way in which the sea was altered; but all of them suffered from gaps and often from manifest errors. It is understandable that it was extremely difficult to make calm observations of a phenomenon that tradition has invested with dreadful characters, and even more so, if one takes into account that it occurred at night and when people were already frightened by the earthquake.

With the exception of Coquimbo, which has electric lights, the darkness in the other ports mentioned must have been complete.

I will indicate the facts that, according to my research, seem to be true, and those that I consider doubtful, pointing out separately the reasons I have for believing so.

The outflows and recollections of the sea have been carried out without violence; they have been like extraordinary ebb and flow, which have reached the extreme levels, in a very short time, less than 30'.

It is said that in Caldera and Coquimbo, the boys of the town used to walk slowly backwards before the rising wave, without the water getting their feet wet. The ebb was produced with a slightly greater speed. In this respect, the narration of the neighbor of Caldera, Don Vicente Incinilla, fifty-six years old, son of fishermen and dedicated to fishing since his childhood, who knows very well the bay of this port and neighboring coves, is interesting. This fisherman considers that Caldera's temperament last November was cold and humid, almost typical of winter. On the night of the 10th, he was in his boat, anchored two miles to the west of the city, in front of the lighthouse, a few meters from the coast, in 15 meters of water. He felt the tremor perfectly and remained alert for one to two hours, waiting for some alteration of the sea, because he knew that these phenomena sometimes go together. However, he did not notice any abnormal movement of the water.

In the vicinity of the lighthouse the coast is steep, so that the advance

and retreat of the sea are very small in the water level changes.

The same informant says he observed distant diffuse lightning flashes to the west during the tremor and denies the effectiveness of the news about the rising of the beach in Flamenco Bay, as reported by some newspapers as a result of the earthquake. The soundings made by the sailors of the "Latorre", the "Chacabuco" and the "Uribe" show, on the other hand, that the seabed has not suffered any modifications.

The data that I collected in the different ports, on the hour in which the waves of the tidal wave appeared, are not in good agreement either. It would have been of particular importance to be able to specify this point, to find out the probable way in which the sea disturbance was propagated.

Among the information of Chañaral that deserved us more confidence, there are those of the merchant in rags, articles of store, drugs, etc., Mr. Juan Trabucco, one of the most damaged neighbors. He tells that at 12h15' there was the first flow of the sea, at 12h30' the second, and at 12h45' the third. Between one and the other rise there was - he says - withdrawal of the water. He believed that always before leaving, the sea receded; but this did not happen the first time.

Dr. P. H. Scholberg, also a resident of Chañaral, has his house on the seashore and very close to the Customs House. With the earthquake, the pendulum clock in his bedroom stopped, and when the earthquake was over, he started it up again. The waters, in their maximum ascent, that reached 2,40~m., over the floor of the rooms, hid the clock and this one remained marking 1h.25' Surely, this data of the third exit of the sea, is more precise than that of Mr. Trabucco.

From these and the almost unanimous inquiries made at all ports, it can be inferred that the third of the flows was the largest.

In the building that currently houses the Chañaral Customs House, located in front of the old building on Freire Street, the water rose up to 1.90 m above street level. In the former Hotel Ingles of Don Francisco Montan, it reached 2.55 m. above the ground. We did not find in Chañaral points marked with respect to the zero or average sea level, that would allow to refer the heights previous to this level. By comparison with a plan of the city, drawn up by the Geography Inspectorate of the Public Works Department, it appears that in the tidal wave, the waters rose up to +5.50~m. above zero. In all these ports, the difference between the extreme tides is approximately 1.50~m.

The red line on the accompanying plan of Chañaral Bay corresponds to the curve at elevation +5.50~m. In this city we did not obtain data of the minimum water levels in its descents.

The Maritime Governor of Caldera, Mr. Rojas, fixes the first exit of the sea in that port, at 12h10'. He speaks that immediately the waters withdrew and advanced several times slowly, without producing damages; that the greater flow took place at 3:00 a.m. on the morning of the 11th, originating the destruction that had to be regretted; that in some ebb and flow a good part of the foundations of the railroad pier remained visible and that these movements of the sea continued becoming smaller and smaller, until after 5:30 a.m.

Mr. Incinilla says that, according to the references of other fishermen, the major outflow seems to have occurred at 3 am on the morning of the 11th, that it was preceded by two minor ones and that immediately before it, there was a large ebb that showed part of the hull of the ex-Blanco, sunk in 25 meters of water. Of water. The latter, which Captain Rojas also claims to have seen, seems doubtful. I visited the site where the vessel is located and I believe that some parts of it must have been uncovered, since this happens at very low tides; but it is difficult to distinguish these parts from the coast, due to the darkness of the night.

The time given by these informants for the maximum flow does not harmonize with that noted in Chañaral, in spite of the fact that the times of the first ascent almost coincide and that the distance between both ports is not great. Neither does it agree with the data collected in Coquimbo, to which I will refer later. These last ones agree better with those of Chañaral, from which it would result that the data of Caldera would be the affected ones of error.

The highest water level left very clear demonstrations at the Caldera Railway Station, as some of the attached photographs, especially No. 96, show. In the Chief's office, these indications were 2.40~m. above the floor and 2.70~m. above the loading dock platform. I calculate that these heights must correspond to a difference of not less than 5.50~m. with respect to zero. Nor did I obtain at Caldera any news of sea falls below mean level.

The data supplied to me in the port of Huasco were quite incomplete. I did not find eyewitnesses of the facts, perhaps for having been very few observers who approached the beach, in the darkness of the night, which must have been very large, because it can be said that in Huasco there is no public lighting. The plant of the town, is at a certain height above the sea and was inaccessible to the tidal wave. The damaged constructions, were the docks and warehouses that are along the narrow and low strip, located between the town itself and the sea, and that possibly were abandoned at that time. No one could say anything precise about the movements of the sea. Samples left on the walls of the cellars of Torres y Cia. indicate that the water rose to 1.20~m. above the threshold of the entrance door. That elevation must be at a height above zero very close to those deduced for Caldera and Chañaral. Towards the mouth of the Huasco river there are low grounds into which the sea went more than 1 km. (see photograph number 97).

The best data obtained are from Coquimbo. The conditions of this city were more favorable to the observations of the tidal wave than those of the other ports visited, especially due to the circumstance of having better lighting. The account of Fidel Araya, a sailor who was on duty at the Customs pier during the night of November 10, is very interesting and seems to be true. His information was confirmed in good part by the engineer of the Public Works Department who directed the construction of the seawall, Mr. Luis Aguayo, who after the tremor occurred, went to the Aduana square to observe the abnormalities of the sea that were already being talked about in the city.

The first rise of the waters, says Araya, took place half an hour after the seismic phenomenon. It occurred slowly, without previous withdrawal from the sea and reached up to near the east sidewalk of the Customs House; that is, up to the level +~2.30~m. above mean tide. Then came the ebb, until the normal level was restored. Almost immediately afterwards, the level rose again, slowly, to the same height as before; it remained there for a short time, and then came a more rapid, almost precipitous, descent of the waters, which continued below zero and reached to dry the bottom of the sea at the head of the passenger wharf. Sounded this point on December 8 last, it proved to have a height of -~5.80~m. with respect to the mean tide. A few moments later came the third rising wave which relatively quickly, but without any violence, marked the maximum level of +~4.60~m. This would explain the assertion of some neighbors, that the wave of the maximum ascent was about 10~m. high, since from our data appears a difference of 10.40~m. Araya calculates approximately 15' the time between the described flows, so that the major outflow must have occurred around 1h. A.M. on the 11th.

In the blue of Coquimbo Bay attached to this report, the curve corresponding to the maximum water level is indicated with a red line.

The most flooded areas were those of the Victoria population, a very poor neighborhood of Coquimbo, located in unhealthy, muddy soil, the formation of which should not have been allowed.

The press gave a timely account of the effects of the tidal wave in other ports where the damage was of lesser importance. To the north, the alteration of the sea was felt as far as the coast of Peru, and to the south as far as the Chiloé Archipelago.

III. - DESTRUCTIVE ACTION OF THE EARTHQUAKE

In the ports visited, the destructive action of the earthquake is not noticed for two clear reasons: because the violence of the movement has been mediocre, due to the existence of rock on the surface of the ground or

at small depths, and because the constructions, in their great majority, are made of wood or light materials well fastened. I will limit myself, then, to speak of the damages of the earthquake observed in Copiapó, Vallenar and Freirina.

The buildings in these towns are old, very modest and poorly preserved. More than half of the houses are made of adobe or mud walls and the rest are made of partitions of slats, cane or branches, always covered with mud. There are so few constructions of other materials that, apart from the cemetery tombs, the drinking water tanks and two or three other buildings, there are no other buildings made of brick, stone, concrete or reinforced concrete.

The construction systems used are invariably the same. With few exceptions, all the buildings seem to have been built by the same architects: they have the same architecture, the same layouts and the same defects. The examination of the deterioration caused by the earthquake shows that the procedures used in the construction suffer from errors due to the ignorance of the most elementary principles of construction, which in an area exposed to seismic shocks cannot be violated without constituting a real attempt against the life of the inhabitants.

If we add to this the fact that Copiapo, Vallenar and, to a great extent, Freirina are located on a soil of inconsistent bearing, we have the explanation of the great damages produced by the earthquake of November 10. Undoubtedly, the prolonged duration of the movement at its maximum intensity has also had an influence, although it has not been one of the greatest known.

At some points, cracks were produced in the ground. Photograph number 1 shows one of them, in the vicinity of Copiapo and photographs numbers 2 and 3, those visited at the Nicolasa hacienda, next to the railroad track between Vallenar and Huasco. The relatively flat terrain here is made up of sand, gravel and gravel. The cracks had a visible depth of about one meter; above, a width of about 0.25~m. and a length of 15 to 20m. Numerous cones between the cracks, up to 0.15~m. high, with a small mouth at the apex, like a crater. Formed of a very fine sand that must have come out in the form of flowing mud, they constituted an evident proof that during the earthquake there has been, by such tears, precipitation of water from the first subway nappes, caused by the settlements of the loose ground.

On the Nicolasa farm itself, shortly before reaching Freirina, there were cases in which straight sections of the railroad track suffered, together with the embankment and fences, transverse slides that formed curves of 100~m. of development and more than 1~m. of deflection. In these parts, the ground had a moderate slope perpendicular to the track. On the neighboring slopes, there was evidence of the tearing and rolling of the ground as a result of the translation of the terrain.

Photograph number 4, although blurred, shows one of these displacements.

The blocks of Vallenar between Nueva Freirina, Marañón, Hospital and Colchagua streets also experienced superficial landslides, with the formation of cracks. The terrain in this area is loose and has an accentuated slope.

In Vallenar and Freirina we heard that in the vicinities there were sinkholes and translations of entire pastures; of the production of considerable cracks, of unknown depth, which threw in abundance a muddy liquid with the odor of petroleum; that these gushers formed cones of more than 1~m. with mouths the size of a fist. In all this, there must have been much exaggeration, because every time I expressed the purpose of visiting such interesting demonstrations the same chroniclers did not point out insurmountable inconveniences for it.

When referring in detail to the construction systems used in the three cities of Atacama to which we have alluded, we will point out the main deteriorations observed in each one and we will indicate the causes that, in our opinion, have had greater influence in their production. In certain

cases, we will also note the way to correct the most common defects that are observed.

The poorest type of house is made of adobe walls, commonly combined with adobe bricks and partitions. Naturally, it has only one floor. This type constitutes no less than 25% of the rooms in these cities. A house of this system, has the exterior walls and those of greater importance of the interior, made of tapiales of approximately 1.0~x~1.5 and 0.60~m. or more in thickness. These blocks do not have any interlocking between each other. The material is some clayey earth mixed with straw, but for lack of it in the vicinity or for economy, even the cohesionless earth of the very site where it is built is used. Generally, the part of the walls located more than 2~m. from the ground is made of adobe. The dividing walls of the pieces are made of partitions, of any of the systems that we will describe later. The roof is formed by a beams of little inclination that is supported in the majority of the cases, almost without bond, on the walls of the contour, and that supports a cover of totora, cane or slats covered with a layer of mud. The foundations, if they exist, do not deserve the name of such, because they do not go deep in the ground, are very little resistant and sometimes detrimental for the stability of the building, as it happens when they consist of round stones of not units with mud, case of the foundations of the Hospital of Vallenar. Photograph number 5.

Photographs numbers 6 and 7 show examples of the described construction that have been left standing, but unusable. Most often they have been completely destroyed, as shown in photographs 8 to 17 inclusive, as they lack resistance against the slightest movement of the ground due to poorly conceived weights and lack of elasticity and even cohesion.

The slightly better type, existing in no lesser proportion is that of adobes, always of a floor or with another, in the high ones, of partitions. It differs from the previous one, in that the adobes replace the adobones. The advantages come from the better quality of the material, the fact that the walls are lighter because they are thinner and that the execution is done more carefully because it is also a more expensive work. The beams that form the door and window reveals, when they extend far to the sides, establish solutions of continuity that facilitate the separation of the upper portion of the walls. The same effect is produced by the devices known as "braces" if they are not connected to the walls by means of well-tied upright feet or effective anchors. A brace is an element of interlocking or reinforcement, formed of two sills and several crosspieces that is used in the walls to engage their mass in the interlocking that are established between them. When the braces are placed at the height of the lintels, they replace them. At the top of the walls they serve as a rest for the roof.

Of the adobe houses visited, the Judge's house in Vallenar, apart from some inexplicable errors, is undoubtedly one of the best built. However, the earthquake produced cracks and detachments of plaster for repairs that were not depreciable. The walls rest on good foundations and have three keys with sills of 0.15~m. joined every certain distance by right feet of equal dimension. These devices, with half-timbered joints, have fulfilled their task of securing the whole.

The keys that I saw in the other constructions, because they are very weak and do not concern the mass of the wall, have constituted evident defects in the works, as shown in photograph number 18.

The roof, if it is resistant and well connected to the walls, is the best element of security against earthquakes in adobe buildings. Unfortunately, in Atacama, this point has been completely neglected: they have only been concerned with defending themselves against the sun, the wind and the scarce rains of the region. Moreover, the roofs suffer from the serious defect of being heavy, as a consequence of the repairs to which they are subjected every time the rains produce leaks. These repairs consist of placing new layers of mud on top of the existing ones. There were cases of roofs whose successive coatings of earth are more than

0.20~m. thick. Photographs 19 and 20 give an idea of this. In the last one it can be seen that the considerable weight of the roof put in movement, made the supporting walls give way.

Photograph number 20 is demonstrating the effectiveness of the roof in supporting an adobe wall that has not been disaggregated. The same result is produced by a second floor of partition walls over an adobe room, as shown in photograph number 21.

Photograph number 23 shows very clearly the effects of the earthquake on a wall more or less well executed but without foundations. The base was previously at the points indicated by the rods driven into the ground and the wall was joined tangentially with the other one, which is seen on the right. Given the great mass of the elements in movement, neither the roof ties nor those of the other wall were of any use in preventing the wall from collapsing later.

It is known that the intensity of earth oscillations decreases rapidly with depth. In mines, vibrations are rare. A deep foundation will transmit fewer movements than a shallow one. In regions exposed to seismic phenomena, it is also necessary that the foundations support the construction with the ground, so that, as far as possible, there is synchronism in the movements. Otherwise, shocks with detrimental consequences may occur. To this must be attributed the real throw that is observed in some fallen objects that have been poorly founded or poorly anchored.

The overturning of the Matta and Atacama monuments, photographs number 24 and 25 can be cited as an example of what has just been said. The efforts in this case must have been enormous, for the great weight that existed in the high part of those works. Something similar has happened to the roof of the house that in the photograph number 17 appears in the foreground, to the right and whose remains can be seen on the floor.

Photograph number 26 represents the ruins of a building of adobe and mud walls, partition walls and mud roof. The adobes have a certain resemblance to a massif of adobes due to the pitting made on the surface to increase the adherence of the plaster.

The chapel and the entrance of the Copiapo Cemetery, adobe constructions with a wooden turret suffered a lamentable destruction, as shown in photograph number 27. Something similar happened to the tombs of the same material that appear in photograph number 28.

In Copiapo the very detrimental influence of the terrain of transport in the earthquake is very noticeable, for the greater destruction that exists in the vicinities of the river. The streets Atacama and Chañarcillo and the cemetery, are the places that perhaps present greater damages.

Characteristic are the cracks in staggered lines and forming X's that many adobe walls present, due, according to all probabilities, to the action of horizontal or oblique thrusts in their plane. See photograph number 29. Such diagonal cracks are always produced, according to the joint lines of the adobes, so that the four triangular portions into which the massif is divided, are separated by destruction of the adherence and without rupture of the adobes. I observed this same thing in some brick sepulchers, in Copiapo, and in the jail of La Serena, a building constructed of the same material. The mortar of the cracks lost its adherence or disintegrated.

Nor is it rare to find houses whose corners have been destroyed by the effect of roof thrusts in the direction of a diagonal, as shown in the sketch; what happens when the support or ties on the walls have not been made uniformly all around and the walls have lacked reinforcing elements.

The third type of house used in Atacama, is the *partition walls* formed by a wooden skeleton *and a filling of adobe bricks*, supported on both sides by slats or wires. This construction constitutes an intermediate procedure between that of reinforced adobe bricks and the partition walls themselves, which we will deal with soon, and meets much better conditions than the two systems described, mainly because of its greater lightness and elasticity. The right feet, generally of 0.10 x 0.10 m., are placed at variable distances between 0.50 and 1m. When the foundations are good and the moorings well arranged, they can withstand the strongest tremors without danger of overturning. However, the damage to the backfill and plastering is so serious that large sums of money must be invested in repairs. This is even more true in the case of adobe bricks reinforced with wires, because these flexible ties do not prevent the loss of synchronism in the oscillations, and the bricks then begin to move in the opposite direction, causing the rupture of some, the displacement of others and the destruction of all the filling and the stucco. See photograph number 30.

If the wire is placed crossed or forming tighter squares, the damage is less, but the mentioned inconvenience will not be completely avoided. The partitions in which the filling is fastened with slats of more or less 2.5 cm. By 5 cms. Every 30 cms. They hold the filling better, as shown in the house on the right of the photograph number 9.

The better performance of the buildings with adobe partition walls compared to those with adobe or rammed earth walls can be seen in photographs 31 and 32, in which, next to some standing houses of the first system, there are others of the second category on the ground.

The two-story houses of partition walls with adobe bricks have greater damage on the second floor than the one-story houses, probably because the oscillations have greater amplitude on the upper floors.

The walls of the first floor, sometimes thicker, are composed of two partitions that leave a hollow in the center, joined at certain intervals by crossbeams. Many stations of the Longitudinal Railroad, made of partitions of the system in question and in which the adobes are fastened with wires, have an exterior plaster of cement mortar about one centimeter thick; stucco that, heavy and fragile, when it has not fallen pushed by the adobes, has remained suspended from the wires in the form of large plates that constitute a danger for employees and travelers.

The next type of house in the ascending scale of this classification is the *partition* house. It consists of a wooden skeleton and a double lining of laths, canes or rods of certain shrubs, plastered with straw. The space between the two faces of each partition is left hollow or filled with branches.

The behavior of such constructions during earthquakes has been far superior to that of the other systems described and when their conception and execution have complied, under ordinary conditions, with the principles of mechanics and material resistance, they have withstood the violence of

the phenomenon in a highly satisfactory manner.

In this type we distinguish the three varieties of partitions already mentioned: slatted, slatted and branches and cane.

The partition walls of the first category are formed by a wooden skeleton covered on both sides with 2 to 3 cm square section laths, also spaced 2 to 3 cm apart. The mud plaster is held in place by its penetration between the wooden elements.

For economy, the partition of the second group is used, which is a variant of the previous one, in which the slats, now, from 2 to 3 cms, are 2 to 3 cms long. By 5 cms. They are placed every 30 cms. and the interior hollow is filled with rods of "churque" or "brea". These names correspond to a hawthorn of the Mimosaceae family and to a plant of the Compositae family, also called sorona. The branches of "churque" and "brea" are hard and resistant to the action of time... As in the previous case, the walls are stuccoed with mud, which adheres very well to the branches of the core.

Finally, there is the *reed partition wall*, in which the internal and external linings are made of reed rods split lengthwise and placed at distances less than their width, which is 2 to 3 cm. The two faces of the partition are plastered with mud and the space between them is left hollow. See photographs number 64 and 95.

The results obtained with these partition systems improve from the first to the third for reasons that need not be repeated. In the last system, only the cane brought from Ecuador and known by the name of Guayaquil cane has been used, which is very similar to our colihue from the south and surely of no better conditions. Its application has been due, perhaps, to freight facilities.

The light layer of plaster is so well bonded to the reed rodding that even the severe shaking caused by the overturning of partition walls poorly fastened to the rest of a construction only partially affected the mud stucco. See, in this regard, photograph number 33.

The behavior of the partition wall of slats and branches is also favorable, as shown in photograph number 34. This little house, still unfinished, did not have its exterior walls plastered. The interior stucco suffered nothing. The façade wall, made of rammed earth, was totally destroyed. Photographs 35 and 35th show other examples of the very different effects of the earthquake on walls of partition walls and adobe.

The plaster on square laths, as in the case of the Copiapo theater, photo number 36, almost always deteriorates. If the laths had grooved edges, with a protruding portion, or if their exterior face were wider than the interior, the results would be improved, because of the double advantage of making a better bonding of the stucco and allowing to reduce its thickness.

In this type of house it is a common mistake to reduce the number of diagonals by relying on the effectiveness of the battens as windbreaks.

The roof of the Copiapo theater sank to a certain extent, in spite of being very light, due to the weakness of the beams and lack of connection with the lateral walls. Given the height and elasticity of the building, the oscillations of the building must have been very large and the loss of synchronism in the movements had a decisive influence. See photographs numbers 36 and 37.

The school of the Nuns of the Immaculate Conception of Vallenar, being of reed-lined partitions, was considerably damaged because the construction suffered from almost unbelievable errors, as can be seen in photograph number 38.

The Copiapó Railway Station offers the most instructive example of the goodness in this region, of the buildings of cane partitions well executed. It is a fifty year old construction that has resisted, without repairs, several earthquakes without ever suffering the slightest damage. The skeleton, very well contravened and tied, of healthy and resistant pine wood, forms a body of a great solidity of set. The stone foundations, with

a good mixture of lime, are sufficiently deep. The Guayaquil cane covering and its mud plaster are preserved in perfect condition. The walls of greater importance have been formed by two partitions with their right feet and sills conveniently united. The space that separates these partitions is empty. The cane coverings have only been executed, as is to be expected, on the visible walls. The beautiful waiting room of the station, photo number 39, which measures 15.60 m. by 13.50 m. in plan and has a height of 5 m., does not present the slightest tear.

The building located in the Copiapó plaza, on the corner of O'Higgins and Chacabuco, is another well-built partition construction.

The churches, generally better built than the private rooms, have remained standing in superior conditions. The one of Vallenar has walls of double partition of canes with right feet of only 10 X 10 cms, and it presents the detached plasters and other damages of not greater importance. Its tower, see photographs numbers 12 and 13, has a solid skeleton of pine, well contravened and they fill the spaces between the pieces of wood blocks, of concrete of more or less 0.15 m. of thickness, perhaps subject to the beams and right feet by iron rods that cross them. The whole is covered by a stucco of cement mortar on wire mesh. The originality of this construction attracts the looks of the visitors and with greater reason when it is heard in the locality that the church of cane partitions has its tower of reinforced concrete.

There has been a serious mistake in adding an enormous weight to the tower in order to give it the appearance of a masonry work. Fortunately, this has not, for the time being, had any unfortunate consequences. The same could have been achieved by doing away with the concrete blocks and just placing the mortar cladding with a more solid wire mesh, stiffened with some new crossbeams.

The Freirina church, photo number 40, also of gray-colored partition walls, shows minor damage.

In the cities visited, houses of all the partition systems described above should account for about 50% of the total number of houses.

I will now deal with the few buildings in the region made of masonry and concrete, alone or reinforced. These observations refer to the ponds of Copiapo and Vallenar, to the sepulchers of the cemetery of the first of these cities and to certain buildings visited in passing in La Serena and Coquimbo. I regret that it was not possible for me to examine other works of special conditions of resistance, such as piers or abutments of bridges, some important culverts of the railroad, etc. The engineers of the railroad company in Copiapo assured me that such works had not suffered from the effects of the earthquake.

In the private construction of these cities, lime mortar has been used almost exclusively, most of the time with a high proportion of sand. I collected samples of mortars so poor that at the slightest pressure of the fingers they disintegrate.

Of the factory constructions of the Copiapó Cemetery, those of masonry (bolón) and lime mixture have experienced a complete destruction, as photographs numbers 41, 42, and 43 attest. The mixture of the first tomb in photograph number 42, compared to the others, is relatively good. However, the consequences of the earthquake on it have not been minor. This and other analogous examples denote not only imperfections of the works, but deficiencies of the system in places of inappropriate terrain, exposed to seismic shocks.

Lesser effects have been seen in brick masonry, and this is quite explainable, given the greater lightness of the material and the much superior bonding of its constituent elements. In spite of everything, the ordinary brick masonry with lime mortar, made without iron reinforcements, have had a behavior that in no case allows advising their use in the area.

The tomb in photograph number 44, built with Hannington brick of excellent quality and a very good lime mixture, is completely destroyed. The photograph shows some slippage of certain portions of the masonry in the plane of the beds, produced after the adhesion of the mortar had been destroyed or after it had been broken by tensile stresses.

It is evident that, except under exceptional conditions, it will always be possible to construct a masonry building, whether of stone or brick, capable of resisting more or less well a strong tremor in bad soil. We will achieve this by using deep and monolithic foundations, making use of suitable reinforced concrete or metallic reinforcements in the walls, and by locking them well with the roof, etc.; but this will not prevent the construction from cracking and causing appreciable deterioration in the plastering. After each important seismic event, the work will require repairs and if these are neglected, the stability of the building may be endangered.

The masonries are very well, when they must support only compressive stresses. They are the definitive works par excellence, as it is proved by the numerous monuments of the most ancient civilizations that are perfectly preserved in our days; but they are imperfect and deficient with another class of solicitations. The elements of a construction during an earthquake can be subjected to any kind of stresses or combination of them. In such cases, the best materials will be those that have similar resistances under different stresses. From this point of view, which we could call uniformity of resistance, steel would be one of the most perfect materials. The masonries whose resistance to the traction, to the adherence or to the torsion are very small, would constitute mediocre materials, Their conditions are notably improved with well arranged metal reinforcements; but these strange elements make the works more expensive and will never make them perfect, no matter how much one resorts to the use of stones or bricks of special intricate forms.

If cement mixtures had been used in the described masonries instead of lime mixtures, the damage noted would naturally have been of much less importance, since the good performance of the masonry depends especially on the quality of the mortar. However, the observations made on this construction system are still valid in all its parts.

The performance of the concrete works of the Copiapo cemetery - although these works are of very poor quality - has been much more satisfactory than that of the masonry. Photograph number 45 represents the niches located on the south side of the main door. The parts that suffered the most were those at the ends. The niches in the central portion were not damaged, because they were supported by each other.

Non-ferrous concrete is also far from homogeneous in its resistance, but it is closer to it than masonry.

The Vallenar drinking water tank, made of concrete with a good dose of cement, withstood the earthquake very well in all the buried part, despite being located in a soil of the Huasco river bed. It is rectangular, with walls of trapezoidal section below and rectangular above, and vertical interior slope. The cover, formed of vaults between iron beams, has, outside the support of the contour, several interior pillars. The tears in this construction occur preferably along the line of the lintels of the windows of the rectangular section of the walls, at a low height from the ground. The different behavior of the two parts of the pond, the buried and the uncovered, is undoubtedly due to the fact that in the horizontal oscillations the first has moved synchronously with the ground that has served as support at all times, while the second has not.

Finally, I arrive at the only reinforced concrete works I visited in the Mediterranean cities of Atacama: the drinking water pond in Copiapó and a tomb in the Copiapó cemetery.

The first is composed of two circular compartments tangent in some

generatrices, with 5 m. of water height and covered with slabs with ribs supported on pillars. The bottom or "radier" is at ground level and perhaps founded on rock. This pond does not present the slightest crack, as it was to be expected given the material of which it is constructed, possessing good resistant properties against different kinds of solicitations.

Photograph number 43 shows the reinforced concrete tomb in the center; the next one is made of reed partitions. To the left and in the background of the photograph number 42, these same two sepulchers are distinguished between the ruins of the masonry ones.

Indirect effects of earthquakes are the fires and the loss of life they cause. I have already said that there were no fires in Copiapó. Neither in Freirina nor in Huasco Bajo. In Vallenar, there were two fires and a fire threat, caused by oil lamps, which were soon extinguished.

The deaths in the urban districts are detailed as follows:

Copiapó with9 ,824 inhabitants..... 70....0.71%.
Vallenar " 6.348 " 333 5,25%
Freirina " 1.403. " 14 2,00%
Lower Huasco less than 600 " ..... 12 nas de 2.00% " ..... 12 nas de 2.00% " .....

IV.-DESTRUCTIVE ACTION OF THE TSUNAMI

At the beginning of this Report, it was stated that the outflows and recollections from the sea were carried out without violence. Apart from the evidence already noted, numerous cases can be cited of works of very little consistency, located very close to the beach or on the beach itself, and which do not show any evidence of having been damaged by the waters. An example of this is the existing seawall in Coquimbo, from the Railway Station to the north, made of dry stones. Photograph number 46 refers to the house of Mr. Juan Vechiola, of Chañaral, also founded on foundations of stones without binder. The water rose there until the board of the highest pier without producing damages in that so disintegrable base.

The shock of the earthquake has been much less on the coast, due to the firmness of the soil. I could cite several cases of constructions similar to those destroyed in Vallenar and Copiapó that in Coquimbo, Huasco or Chañaral have suffered little. Suffice it to point out, for now, the example of photograph number 47, of the chimneys in poor condition of an old copper smelter in Huasco, abandoned for years.

The enormous destruction of the neighborhoods invaded by the sea in Chañaral and Coquimbo and the damages in Huasco and Caldera were due to the tendency of the wooden constructions to float, to the collisions of one against the other while moving over the water or to the pressures exerted on the walls due to differences in level between the exterior liquid and the one that penetrated or had already entered the interior.

I have named the four ports that suffered the most damage from the tsunami, in order of the importance of the losses experienced. The city of Chañaral saw the disappearance of the most valuable sectors of its plant, which were reduced to an overcrowding of debris and with them, it lost all of its commercial stock.

Photograph number 54 shows the damage caused by the sea to the Customs building and is also proof of the moderate violence of the earthquake on the coast because of the good shape in which the tall brick chimneys of the old Edwards foundry have survived. The deterioration of the stone cladding of the seawall on its slope was due to a rough sea in 1920.

The vast majority of the houses in Chañaral were made of wood. The primary cause of their destruction was the uneven buoyancy of their various parts. When the floors were resistant and the bases were uniformly and totally detached from the foundations, the buildings were in a seaworthy condition.

In the photograph number 55, you can appreciate the change of place made by the house of the Resguardo de Caldera, without showing damages that deserve to be mentioned. It is the one that appears to the right and that before was next to the other house of the photograph ? With its greater length perpendicular to the beach. View number 57, taken from the start of the passenger pier, shows another side of the Reguardo in its new location, obstructing access to the pier. The foundations have been left intact, as seen in photograph number 57.

The small house of the Coquimbo guardhouse, which appears in the foreground on the right of photograph 58, on the lawns of the small square, was once located near the seawall. However, generally these wooden constructions submitted to flotation, were opened and destroyed, as it happened with the building of the Customs of Caldera. See photographs numbers 59, 60, 61 and 62. That building split into halves: one turned 90° and remained standing; but the other, colliding with the station equipment hold, collapsed. The warehouse, a building of cane partitions, suffered, on the other hand, the rupture of several right feet, as shown in photographs numbers 63 and 64, due to the effect, it seems, of the collision of the

numerous cars, which, detached from their "bogies", sailed, hooked, from the railroad pier to the beach of the baths. See photographs numbers 65, 66, 67 and 68 and the plan of the bay.

In Chañaral, the collisions of the houses moved by the water, that, as in Coquimbo, have constituted the second cause of destruction, have had more disastrous consequences, by the constant agitation of the sea in that port. Photograph number 69, taken from a gallery of the former English Hotel, gives an idea of what has been said, and also demonstrates the confidence with which it was built on the water's edge, without any effective protection against the swell on stormy days. In the living force of the collisions, the mass of the floating bodies had a preponderant influence, since the speed must have been small.

The third of the destructive motives during the floods of the tsunami is found in the unevenness of water that occurred between the interior and the exterior of the buildings. In well connected constructions, the water entered very slowly into the interior, so that the greater height of the exterior liquid produced important pressures on the walls. Conversely, during ebb and flow, the water from the outside withdrew relatively quickly and the water from the inside took a long time to drain, causing pressures in the opposite direction to the previous ones and much more dangerous, since the constructions usually lacked elements to support horizontal thrusts directed from the inside to the outside, while in the other case, the walls were supported by each other.

In this way, it is easy to explain some curious facts that many people could not understand. For example, in the same house, there were adjoining rooms that presented the one with its furniture and other belongings in the most complete disorder and destruction, and the other, everything intact and in its place, Examining the construction, it was then discovered that in the first room, the water had difficulty to enter at first and that it did so violently when the pressure opened a door or broke the glass of a window. But the most common cause of the collapse of the best executed buildings was the rupture of the walls towards the exterior due to the effect of the water load that, when the sea withdrew, took a long time to empty. The houses with wooden partition walls or galvanized iron sheets were opened as shown in the attached sketch.

Such seems to have been the action of the water in the warehouses of the Coquimbo Agencies Company referred to in photographs numbers 70, 71 and 72.

In Chañaral, the destruction of the building of the store "La Mina de Oro" of Mr. Rubio Hermanos, in which the walls collapsed towards the street turning on the foundations, as if these had been a hinge, is another example of what I have been explaining. I was saying about this construction that it was of reinforced concrete and as it was destroyed by the tidal wave, pessimistic judgments of the system were emitted in the locality. By clarifying things, it can be seen that the cause of its destruction was due to a bad construction procedure and that this work could not be called reinforced concrete. In fact, it consisted of a weak iron skeleton, formed by two 10 kgs. per meter straight legs of two rails, with a 0.25 m. thick backfill of bad concrete without sand. The panels between the right feet, when filled, had two 25 mm square iron cross suspenders. The rest of the framework was made up of other iron bars, brackets, and poorly chosen and poorly placed joint plates of low resistance. The concrete, extremely porous, had a dose of cement only admissible in filling cubes, and there was almost no interlocking of the walls with each other and with the roof. Needless to say, there was no adhesion between the iron and the concrete. Externally, the walls were covered with a thin expanded metal mesh, for stucco, with a mortar plaster.

The Torres y Cía. warehouse in Huasco was damaged for similar reasons. This building was made of adobe bricks with bolon foundations and a mixture

of lime and cement on three sides. The foundations on the west side were made of stones joined with mud. The north and east walls, which were also the highest, gave way.

I will cite the destruction of the abandoned building of the coal bunkers of the Navy, in Caldera, as a last example of the destructive action of the sea due to the difference in level. Here the deteriorations have been produced with the first ascents of the water, because the fallen materials were thrown inward and the walls are depressed in the same direction.

The construction is of wood; the foundations are of copper slag blocks joined with cement mortar and an inner core of concrete. The base sills had iron suspenders at certain distances to counteract the thrust of the coal. Therefore, this building lacked resistance against external pressures. In passing, I will refer to two major defects of the foundations of the coal bunkers: their lack of penetration into the ground and the poor bond between the central concrete and the lateral block linings, which easily separated along the entire elevation of the wall.

Coquimbo lost in the tsunami the whole sector of the Victoria population and experienced important damages in the Railroad Station and in the commercial warehouses near the beach. The building, modest and bad, of the working class neighborhood just mentioned was made of wood and partitions of the different types described in this memoir. The causes of its destruction are also the same as those indicated above.

Photographs numbers 74 to 81 and 82 and 83 give an idea of the destruction in the Victoria settlement and at the station.

In the port of Huasco, the main buildings damaged were the Customs House, the old railroad station, now a warehouse, the old forge and the warehouses of Torres y Cia. and Crayg y Cia. We were informed in Huasco that in Carrizal Bajo, the tidal wave had caused enormous damage; the dock, the forge and the railroad rolling stock were destroyed, and the large installations of the Carrizal Mines and Foundries company were seriously damaged.

The movement of the water in its advances and retreats produced certain drags, of some effect only in very loose sandy terrain, as happened on the Huasco railroad and on the Caldera branch line to the smelting Copper Co. See photograph number 84.

Apart from the buildings, most of the docks in Chañaral, Huasco and Coquimbo have been damaged by the tsunami, due to one of the first two reasons I have mentioned, or both combined.

The Caldera railroad pier, a kind of jetty with a sand core, shows negligible damage, as shown in photograph number 85. The passenger pier of the same port and that of Huasco, photographs numbers 86 and 87, in spite of their poor condition and having been completely submerged in the water, suffered no damage.

The Huasco railroad pier, photographs numbers 88 and 89, sank in its central part and as a result was deformed to the boot.

The small, poorly constructed cargo wharves, improperly called "chazas", a name that corresponds to small breakwaters filled with stone, in the port of Huasco, experienced very serious damages. Among them are those of Grayg y Cía., Wiegand y Cía. and Torres y Cía. It seems that the damage was due to the collisions of merchandise, railroad cars and other floating bodies.

The seawall of Chañaral, which has been damaged by some rough seas, especially the one in 1920 that caused the crack in photograph number 90, did not suffer from the tidal wave. Neither could I note any new damage to the pier of the old Edwards foundry in that port, apart from the very serious ones produced in 1920.

Photographs numbers 91, 92 and 93, referring to the Coquimbo passenger dock, the small fiscal dock in possession of Mac-Auliffe and the esplanade under construction of the railroads, show other damages and effects of the tidal wave in that port.

The reinforced concrete seawall, recently built by the General Hydraulic Inspectorate, photographs 91 and 94, shows minor damage to the sections of its wooden paving, corresponding to the expansion joints. The air that was trapped between the ribs of the floor during the rise of the water was pressurized and caused the galvanized iron joint covers with the paving stones belonging to each one to burst. With the road thus prepared, it was very easy for the adjacent paving stones to detach by flotation. Photographs numbers 95 to 104 help to illustrate some of the points discussed in this report or others related to my commission.

V.-RECOMMENDABLE CONSTRUCTIONS AND PROCEDURES ACCORDING TO OUR INVESTIGATIONS

The detailed exposition that has been made of the main constructive defects to which I attribute the damages produced by the earthquake of November 10 and of the causes of destruction coming from the alterations of the sea allows me to be brief in this chapter. I will deal first with the effects of the earthquake and then with those of the tidal wave.

In regions exposed to seismic phenomena, only suitable materials of the highest quality and well-defined construction procedures should be used in order to be protected from disturbing consequences. Unfortunately, this ideal can rarely be achieved in practice. The economic difficulties, the lack of appropriate materials, the lack of competent contractors and operators for its good use, the custom, are so many other reasons that oppose its realization. The influence of these factors cannot be denied; an influence that even the painful trials of the most recent catastrophes do not manage to annul, since the need of individuals to have rooms in which to live cannot be postponed, while the inconveniences to build in the due form, generally are eliminated with slowness.

The type of soil also has a considerable influence on the effect of earthquakes on buildings. Whenever possible, it should be built on firm ground; but in practice, more often than not, the site on which the works should be erected is fixed by other considerations and must be accepted, knowing that the soil is bad. The necessary precautions must, however, be taken with it.

With the preceding ideas in mind, I will develop the conclusions I have reached, beginning with private buildings and ending with municipal and public works. I will not point out the details that must be common to all good construction, as they are well known, and because to mention them would take me away from the purpose of this Memoir.

1.°.-While there is no legislation in our country on the Urban building and the requirements that the works must fulfill to allow its execution are not established, by means of appropriate Regulations to each region, it will be illusory to think that the constructive procedures today in practice are improved. The adoption of these measures is therefore a prior matter. The regulation should cover everything related to the execution of new and repair works: approval of the projects, special specifications, supervision of the works, testing of the constructions and their reception. Fortunately, the Government has recognized the great importance of the problem of our urban construction and has recently sent to Congress a bill on the subject. The practice of allowing only those with good will to build should not continue any longer.

2.°.-In the construction of areas exposed to tremors, the use of adobe or walling should be proscribed. Even if the clay available were of good quality, its use would require preparation and vigilance impossible to achieve in most cases. On the other hand, the wooden reinforcements that would be required to make the works admissible would make them prohibitive.

3°.-The constructions of adobe bricks, suitably reinforced, can be allowed in the northern provinces; but subjected to strict conditions in

each one of their details. The following points must be studied with special care: disposition in plan of the foundations, depth, thickness and class of material that suits, according to the foundation soil; quality of the adobes; keys and other elements of reinforcement; thicknesses, spacing and assemblies of the beams and other wooden pieces; distribution of the partition walls, of the doors and windows; disposition of the roof, rest and tie of it with the walls. These buildings may have a second floor, which will always be light, of partition walls, well counterbalanced and well connected to the first floor. In the absence of more direct and proven procedures to judge the resistance against tremors, the constructions will have to be verified to the action of a wind of at least 150 Ks per m2, working in any direction. If it is founded on rock, the required conditions can be made less rigorous and even the reinforcements can be greatly simplified.

3.°.-The buildings of partition walls with adobe bricks have, in principle, from our point of view, better conditions than those of adobe bricks. The details should also be taken care of, as expressed in the previous paragraph, and the general wind checks should be carried out for all kinds of works exposed to tremors. For adobe bricks, slatted supports should be preferred to wire supports, arranged as shown in the sketch.

In order for the mud lining to be fastened to the wooden elements, a special section should be given to them or nails should be placed in the middle of the penetration. Instead of the filling of adobes it is very preferable to use slag blocks with the indispensable dose of binder to give them the form. These buildings can have two floors.

4.°.-As a more modest room in regions subject to earthquakes can be recommended the partition walls themselves. Of the three varieties of this system described, namely, of slats, of slats and branches, and of reeds, it will be preferable the one that in this enumeration occupies a later place. These constructions can also be of two stories. It is convenient to avoid that in case of fire the hollows of the partitions produce draft, as a chimney, obstructing them every certain distance with pieces of wood, with slag, mud, etc. The laths must allow the mud to adhere in good form.

5°.-The houses entirely of wood or with outer coating of galvanized iron are essentially anti-seismic buildings; but it is necessary to adopt with them special precautions against the fires. More expensive than those of the previous number, they can be destined to private houses, surrounding them with gardens and impregnating the wood with substances that make them hardly inflammable. The hollow space in the walls can be filled with slag to prevent the propagation of sound and the existence of rats.

6°.- The economical, hygienic, light, classic, elegant and less combustible room than the previous one is the one with a wooden skeleton and double metal siding unfolded with cement mortar plaster on the outside and plaster on the inside. To ensure good conservation and adherence of the stucco, it is advisable to place mesh stiffening strips and protruding nails on the right feet, diagonals and crosspieces. The plaster does not adhere to the wood and if they are weak, it makes them bend; if they are strong, it oxidizes them superficially, which is why the plaster should not be too thin, otherwise unpleasant rust stains will appear on the surface.

7°.-The ordinary factory buildings should not be allowed in the cities of Atacama and Coquimbo, but when they are founded in rock or in a very firm ground. In the other cases, they must have a solid skeleton of reinforced concrete or iron, so that the masonry serves only to fill the openings between right feet, beams and diagonals. Hollow bricks, which are lighter and stronger, are preferred for this purpose.

8°.-The definitive constructions, of long duration, in the region that occupies us, are of reinforced concrete and those of iron with concrete filling. For the latter to be lighter, slag or brick concrete can be used.

If we were able to banish the poor, unhygienic and unsafe adobe dwellings that are so widely used today, we would take a great step forward in our urban building systems.

It would seem to be excused to insist on the quality of the materials to be used in the described constructions, on the dosage of the mortars and concretes, on the execution of the works, etc. Etc. Everything must be of the best available in relation to the nature of the work to be executed. In addition, it is indispensable that such buildings have good foundations; that they are well fastened in all senses; that the upper parts are light, especially the roof; that, as far as possible, they have a certain elasticity.

For the reconstruction according to the new systems the difficulties that we have enumerated will be present; but with an intelligent regulation, with the help of the State, and thanks to the persuasive work of the technicians and the experience of the first works, the rational methods will open the way. Within a not exaggerated period of time, the anti-seismic buildings will be more economical than the old ones because of the fewer repairs they will require.

The constructions mentioned above also have indirect advantages. With the large-scale use of wood, previously unknown markets would be opened to the sawmills of the South. The gypsum industry could be developed in Atacama, where it is said that there are rich deposits, protected by the consumption that the new methods would ensure. The working element will be instructed in more perfected building procedures; the monotony and heaviness of the damaged cities would disappear, since more beautiful and daring works could be executed, etc. etc. etc.

In Copiapó, Vallenar Freirina, Huasco Bajo, etc., we would therefore shorten the following house systems:

a) For workers, those of partition walls made of slats, slats and branches or reeds, covered with mud, as in paragraph 4°.

b) For employees, those of wood as in number 5° or those of partition walls with cement mortar and plaster coating referred to in number 6°.

c) For family residences, those of the previous paragraph or some economical types of reinforced concrete only, or reinforced concrete with brick masonry infill or light concrete made of crushed bricks or slag;

d) For public, charitable, municipal, banking, industrial, religious or private association establishments, buildings of reinforced concrete or iron skeleton and concrete infill of number 8. Also those of reinforced concrete with masonry infill or of a light concrete of those indicated in c.

Of course, this classification is only of a general nature. In practice, depending on the particular circumstances, it will necessarily have to be modified and it is most likely that intermediate solutions resulting from the combination of the different types will be adopted.

Regarding the engineering works of Atacama, the conclusion that seems to be derived according to what I was informed, since there were very few that we were able to visit, is that when the foundations have been deep, seated on a rocky ground or on another of great solidity, and when they have been well executed they have not suffered from the earthquake. This inference refers especially to the masonries of

stones with good cement mix and concrete works.

The tsunami experience has suggested to me the following conclusions:

1°) In populations exposed to flooding, any tendency of buildings to float must be absolutely prevented by anchoring them to the foundations when they are light. This eliminates two causes of destruction:

from partial buoyancy and from the collisions of the houses with each other.

2°) The walls must be able to withstand the pressures from the outside to the inside and the inverse pressures corresponding to the load or water level difference that may occur in the event of flooding.

In certain constructions, as in warehouses, workshops, industrial establishments, etc., the solution against the danger enunciated will consist of giving free access to the water on all sides and thus to avoid

that unevennesses are formed. Other times it will be convenient to execute the foundations up to the maximum height of the floods, making them either watertight, in which case they must be more resistant, or with openings for the entrance of the water.

But if for some compelling reason, of which there is no scarcity in practice, a dwelling house is built which is liable to be flooded, the walls must be checked as has been said. It is not easy to predict what will be the load which in any given case will be produced, as it will depend 'on whether or not the room is well joined, on the strength and tightness of the doors and windows, etc. It would be an exaggeration to suppose that water will never enter the interior, since not many doors will support without opening a load greater than 1.50 m., and in addition, the window panes with less than 0.80 m. are broken if they have not been previously broken by floating bodies. The maximum value of 1.50 m. to 2 m. would therefore seem to be justified. As the introduction of water into the rooms will always be unavoidable, it is better to allow it to enter with little load, as this will reduce the damage to household goods; in other words, very strong doors will not be suitable. Precautions should be taken so that in the withdrawal of the waters the doors do not close. The pushes from inside to outside in the current constructions, are the most dangerous.

The houses of the neighbors of Chañaral Dr. Scholberg and Mr. Vechiola, mentioned above, did not float and the sea did not destroy them because they let the water in and out at all times. They were also fortunate not to receive strong shocks from floating bodies.

All the constructive systems indicated as applicable in the interior of Atacama, are with greater reason and in the same order on the coast. The mud lining of some types detaches when submerged in the water, as was seen when speaking of the hold of the Caldera railroad equipment; but this does not constitute a very serious inconvenience in the presence of the other ravages of a flood.

VI. 6 PROBLEMS ARISING FROM THE SITUATION CREATED BY THE NOVEMBER 10 CATASTROPHE

It is not for me to deal with the most serious problems that must be solved in the North as a result of the last earthquake and the subsequent sea departures, which are the aid to be given to the victims and the financial plan that will provide the necessary funds.

The legislative chambers have been concerned with these matters and it will not be long before a law is passed to resolve such delicate issues.

The Government, for its part, zealous in attending to the problems of reconstruction, entrusted its study to a Commission of engineers and architects who, after carrying out the necessary investigations in the field, proposed the way to carry out the transformations of the cities in distress, in accordance with the principles that the state of progress of the country demands.

I have, therefore, little to say under the heading that heads this chapter, and I will refer only to some of the difficulties of the cities of the North that have a bearing on my task.

Chañaral Rebuilding

The data that we have given of the tidal wave are enough to discard some ideas insinuated to defend Chañaral of new incursions of the sea, relative to the execution of a great seawall in the coast of the city. The length of the work, its considerable height so that it would be of use in what is desired, the filling to form a planada are factors that make us think of sums of money too high.

The neighbors, frightened by the catastrophe and convinced that the most economical radical solution to avoid its repetition was to change the

location of the destroyed sectors, agreed to request the Government to found a new neighborhood in the Conchuelas ravine, located behind the present town and towards the hill. A fiscal engineer drew the building plan in the chosen area. The Railway Company also conceived the idea of moving the station to that site, which would protect it from flooding and would also provide a positive service to the city, since the station is currently very far from the center.

However, I am suspicious of the formation of the population in the aforementioned ravine, because of its inconvenient access and because it is far from the points that by their nature should constitute the commercial center; because it should not be forgotten that the devastated area of Chañaral has been that of the businesses.

The problem of reconstruction here does not take on the characteristics of an imperious and unpostponable necessity, as in other cities, since the number of houses since the years in which the metallurgical establishments were closed has been much greater than the population demands. Many houses have remained on loan with no greater obligation for the occupant than that of their guardianship. For the time being, the damaged families and some business positions have been distributed in the uninjured portion of the town.

In my opinion, Chañaral's difficulties could be solved in this way:

The strip between the sea and Freire, Merino Jarpa and Conchuelas streets, and from here a straight line that reaches Varela and extends along this street to the East, would not be allowed to be built in any way, and would be used for mineral deposits, playing fields, etc. In the area that continues towards the hill, starting from the previous line and up to the contour line + 5 m. it could be built; but adopting measures against the effects of a flood and taking into account the level to which the water can reach in the streets. Owners willing to surrender their sites for the purposes of the first condition, would be paid at a fair appraisal by experts if there is no agreement between the parties. With such a solution, there would probably be no need to found a new working class neighborhood.

The houses of Chañaral are all of wood, system very well chosen for the region. It could be improved using in the partitions some filling of those indicated in this report. The other types cited as possible application in the interior of Atacama, with greater reason as s: has been said they are in the coast. bearing in mind, however, the inconvenience indicated for the buildings covered with mud in zones that can invade the sea.

Copiapó Re-construction

The constant concern of the authorities of this city must be to see to it that it is rebuilt in a manner adequate to the unfavorable conditions of its soil to withstand earthquakes. It has been said that the greatest difficulty for this lies in the lack of funds with which to hire a technician to take charge of the new service. In the particular case of Copiapó the objection is not of much force, since there reside there, apart from the engineer of the province, three engineers of the Railroads, any of which would render their services to the city in equitable conditions. The mode of raising the funds intended for the staff of Inspectors, would be settled by the Law referred to in a former chapter. The width of the streets. which is reduced, does not offer serious inconveniences as long as one-story houses are built.

Re-construction of Vallenar

This is the city that has suffered the most from the November earthquake, since its destruction has been almost complete. There are, naturally, not few buildings left standing, habitable; but they need very important repairs to be in conditions of medium security.

With very good sense, most of the inhabitants have wished to take

advantage of the unique circumstances of this disaster to get Vallenar out of the bad place it is in. From the construction point of view, the relocation would also be profitable. A soil of greater solidity could be chosen, with less humidity and not exposed to flooding. All these conditions would contribute to making the works cheaper and longer lasting.

Re-construction of Freirina

The damage caused by the earthquake in Freirina has been considerable. While it is true that most of the houses are still standing, they will require major repairs.

Most of its soil does not meet conditions favorable to resistance.

of buildings against seismic shocks.

The buildings have been made of rammed earth, adobe and partition walls. The buildings of the last system have shown a better behavior, but as they have always been weak and poorly counter-ventilated, they have also been badly damaged.

The reconstruction of Freirina in due form will be more difficult than that of the other cities of Atacama due to its isolation, lack of elements and money.