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SUBSIDENCE IN A PART OF HUTCHINSON, KANSAS

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Introduction

Local subsidence of the earth's surface is a phenomenon which has been observed very many times in very many parts of the world. The causes of such subsidence are familiar to geologists and mining engineers, and indeed in few cases is special technical knowledge required to understand them. If an opening is made beneath the earth's surface either naturally as by underground waters, or by the work of men in mining, the weight of the rocks above the opening presses downward and tends to close the cavity. If this weight is greater than the strength of the rocks, there is a gradual or sudden collapse until there is a stable support for the rocks beneath the earth's surface.

If the relative size of a subterranean opening is small or if the strength of the rocks is sufficiently great, there is a permanent stable support for the overlying rock material, the stresses being distributed in the vicinity of the opening in the general fashion of an arch. On the other hand, if the rocks are relatively weak, or if the opening is large, there will inevitably be ultimate failure and the rocks above will sink down to fill more or less completely the opening which previously existed. In almost all mining operations, therefore, it is imperative to plan the size of the openings so as to permit no serious risk of failure of the roof and collapse of the mine, this without primary regard to the effects of subsidence at the surface.

In certain types of rocks, especially weak shales, a special factor is introduced in the tendency of parts of the roof to fall away, and for the shape of the opening and particularly the thickness of the material above the cavity to undergo more or less radical change. It should be pointed out that in all cases where the size of the opening exceeds rock strength, in the formation of a permanently stable arch support, there will be immediate

or ultimate collapse and subsidence.

In very many parts of the United States and in foreign countries there are numerous cases of subsidence of the surface due to the formation of natural openings beneath the ground. Such subsidences are chiefly found in regions of limestone or other readily soluble material. The subsidences are in some cases very sudden, and considerable. In others, they are gradual and a depression is formed at the surface which is known as a sink.

In the case of openings due to mining operations, the occurrence of subsidence is essentially similar to that under natural conditions except that since mining is undertaken in many cases where the overlying rocks are relatively weak, the subsidence is in these instances somewhat more rapid and pronounced. Where operations extend beneath cities there have been serious troubles from the subsidence of the surface. Notable examples are coal cities in Pennsylvania, salt mining areas in England and on the continent, and in lead and zinc mining in southeastern Kansas and southwestern Missouri.

Subsidence at Hutchinson

For a number of years the salt which underlies the city of Hutchinson has been mined by the drilling of wells and the extraction of salt in the form of brine. Subsequently, shafts have been sunk to the salt beds, and the salt extracted by room and pillar mining.

Since, in the vicinity of Hutchinson, the salt is overlain only by relatively weak, incompetent shale with unconsolidated sands and gravel next the surface, it is obvious that the materials above the salt are not strong enough to support the weight of a considerable mass of overlying rocks for any large opening. Particularly in the case of cavities produced by brine wells where there is no possible control of the size or shape of the opening, it is inevitable that subsidence should not ultimately occur in places where the openings become sufficiently large to cause failure of the roof either at once or due to gradual sapping of the roof so as gradually to weaken it to the point

of failure.

In 1914, considerable subsidence took place in the vicinity of the salt wells of the Norton plant southwest of Hutchinson. Such subsidence may damage or possibly destroy the surface value of land, but if the value of the material extracted from beneath the surface is sufficiently great, this damage is not serious. The land may be no longer fit for farming, but the material loss is not great.

The excavation of considerable openings beneath a part of a city such as Hutchinson is a matter of definite and some considerable risk, in view of the possible subsidence of the surface which may endanger buildings and destroy large property values. Following the subsidence near the Norton plant, there seems to have been a realization of this and operations of the Carey plant, which had been conducted in a portion of the heart of the city, were gradually transferred to a place outside of the city to the east. With knowledge of the strong likelihood of subsidence in the region of salt extraction within the city adjacent to the Carey salt wells, it is unfortunate that a careful investigation of the situation within the city of Hutchinson was not made at that time and means taken to prevent so far as possible any future subsidence. The writer is informed that in a report submitted by Prof. Erasmus Haworth at that time, it was urgently recommended that such steps be taken at that time.

Quite in accordance with the expectation that subsidence might be expected in the vicinity of the Carey salt operations, indications of such subsidence actually appeared to^{ward} the end of February, 1925, and have been the occasion of careful engineering measurements by Messrs. Stacey and Lee, county and city engineers respectively and of examinations on the ground by the writer, March 4th and 5th. The area affected is a circular tract approximately 100 yards in radius, centering near the vicinity of one of the Carey wells which had in the later years of operation been used as the inlet fresh water in the brine ex-

traction operations. Dominant lateral movement in the border zone of the circular area is indicated by tension cracks in sidewalk, gutters, paving and in various buildings, notably the county court house, northwest of the well mentioned. In this building especially the movement was such as to cause serious damage to the structure. In the central part of the area affected, was evidence of some compression seen in buckling of pavements and adjacent brick work flooring, and here also was observed the maximum amount of vertical subsidence, amounting in approximately three weeks to four inches. As might be anticipated, the movement has been dominantly in a lateral direction toward the border of the affected area and the largest vertical movement is in the center of the subsidence area. The rate of subsidence has been very slow, only a fraction of an inch per day. Except for its occurrence in the city where paving and large buildings have shown the effects of the movement, it would have been certainly quite unnoted.

Cause of the Subsidence.

The brief general conditions which lead to surface subsidence which have been given and the observation of previous subsidence in the vicinity of the salt operations in the Martin plant together with the location of the subsidence which has recently taken place in the central part of the city of Hutchinson permits no question at all as to the cause of the movement. The removal of salt by the brine wells and the probable scaling off and dropping down of fragments of the overlying shale have so weakened the strata now extending across the openings that there has been a slight yield. The chief question which arises relates to the probable amount of the total subsidence which may be expected and the prospective rate of the subsidence. The chief difficulty in answering these queries in categorical terms is the complete lack of information concerning the exact shape and size of individual cavities adjacent to the salt brine wells. How thick or how thin the shale cover above these openings may now be is also an unknown quantity. One can merely point out that the geological conditions are such as especially to

result in subsidence, to call attention to certain conditions which make the possible effect of subsidence of a somewhat special sort and to find out whatever means of remedying the situation that may be available. In addition to the strong probability or practical certainty of ultimate failure of the roof portions of large openings beneath Hutchinson, special attention may be drawn to the fact that the city is built on the unconsolidated sands and water bearing gravels of the Arkansas River flood plain. It is obvious that in the event of the opening of any of the considerable salt cavities so as to admit the surface sands, one hundred or more feet thick, would be a very serious and immediate subsidence of the area above this. To this extent the conditions at Hutchinson are different and they are more serious than in the case of many regions of slight subsidence where the bed rocks extend clear to the surface.

Possible Remedy.

The nature of the movement in the vicinity of the county court house at Hutchinson which has taken place so far, indicates to the writer that up to the present time, only a slight sag of the shale roof over a portion of the brine well openings has taken place. There is no indication of the transfer of any of the river sands or gravels to openings lower down. This gradual settling of a part of the shale roof is very possibly the cause of the irregular artesian flow of the brine from some of the wells notably that in the engine room of the Carey plant. It is very possible that the subsidence which has taken place may halt for a longer or shorter time or it is equally possible that the rate of subsidence may increase. There are absolutely no data for estimation of this so far as known.

The remedy which in this case seems obvious is to undertake some means to replace the support which has been removed in the extraction of the salt by the brine well mining. Because the shape and size of the salt openings are unknown, this task is in many ways much more difficult than in the case of

fillings of mines. Nevertheless, it will probably be possible to prevent continued subsidence by filling as much of the cavities as possible with sand which is very conveniently at hand in the flood plain which ^{underlies} ~~exposes~~ all of the city. Careful consideration of the problem leads to the conclusion that unless this area is to be abandoned to whatever subsidence may in future take place, without attempt to protect the present surface, as much sand as possible should be introduced into the openings below ground. It is probable that present wells can be used only in part if at all for this operation, and it is probably desirable in any case to drill test wells to determine the thickness of the shale cover and to use such wells as a means of filling the openings with sand.

In getting the sand down into the cavities, it will be necessary to use only enough water to lubricate the sand, and prevent clogging of the pipes. It is here unnecessary and it is obviously undesirable to introduce a large amount of water along with the sand, though of course if the sand is pumped from the river approximately nine times as much water as sand will be required in transporting as far as the well where the sand is to be put below ground, ^{sand de-watered before putting in well} It is of course readily possible to avoid increasing the size of the cavities below ground, due to solution of salt by fresh water introduced, by substituting brine taken from one of the wells for mixing with the sand. As stated above, there is minimum occasion to use a current of water in carrying sand through a vertical pipe. The main problem arises in connection with exactly where the sand will go after it has been introduced to the openings in the salt. During fillings of mines, the sand is led directly to the point where it is desired to deposit it. In the case of these openings of unknown size and shape, it is necessary to depend in an undesirable degree on the natural distribution of the sand so as to fill to as large an extent as possible the cavities which are now present.

The writer believes that if active steps are taken to fill to as large an extent as possible the openings in these old workings most of the

danger of subsidence will be removed, for the openings left unfilled with sand are likely to be of such size as not to occasion serious danger of collapse. The total size of the openings below ground, estimated at between 150,000 and 200,000 cu. yds., represents an area of one city block of average size, 300 feet on a side, and a height of 40 or 50 feet. That is, if all the salt which has been taken from the irregularly shaped openings in the ground were available and could be piled on a city block it would make an even height all over the block of 40 or 50 feet. Since the openings are widely scattered and very irregular, it is very probable that only a part can be filled. Filling operations should be centered on the area which has already shown a tendency to subside. The expense of this filling probably represents only a fraction of property values at the surface in the area affected.