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CAUSES THAT DETERMINED THE COLLAPSE OF SOME POLES FROM ELECTRICAL NETWORK IN PUBLIC TRANSPORT. CASE STUDY

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Abstract: *In most cases, the elements supporting the electrical power supply networks of the public transport are made of prefabricated concrete poles with longitudinal reinforcement passive or active, by pretension. Position by poles above the road which are exposed permanently action of climatic factors and seasonal action, antifreeze protection for roads, agents used in winter for the maintenance of the roadway. The case study presented in this paper is based on an analysis and evaluation of the causes that produced failure of two poles supporting electric public transport network in Brasov, following an accidental exploitation actions.*

Key words: *poles, corrosion, concrete durability*

1. General Presentation
1.1. Information about Case Study

Maintenance and equipping with an improper position of the poles by the wrong electrical network fixings, attaching additional weights or execute holes uncontrolled section for different functional adaptations cause internal forces and displacement states additional to those considered in the design.

The case study presented in the paper was due to a failure of derailment trolley poles (together contact shoes) electric power network, from a moving trolleybus belonging public transportation [7].

Detachment trolley poles occurred in an area of change of direction and shock induced network failure caused by breaking the support poles of intersection, noted FC-4 in Figure 1. Fall of pole over electrical power network route perpendicular wires induced in this an effect of tensile and balance, which was submitted to the poles sustaining the form of lateral tensile forces. The action lateral tension force caused the collapse support pillars SF8-11, located about 105m away from the first pole FC4, see Figure 1.

1.2. Data about Supporting Poles

Reinforced concrete and prestressed concrete poles using to elements from support the electricity network for public transport was a practice use during the years 1970-1990 in Romania. Therefore, the entire network of poles has a considerable years of service.

Type of the poles after initial tension induced in concrete could possibly be: passive reinforcement not preloaded or

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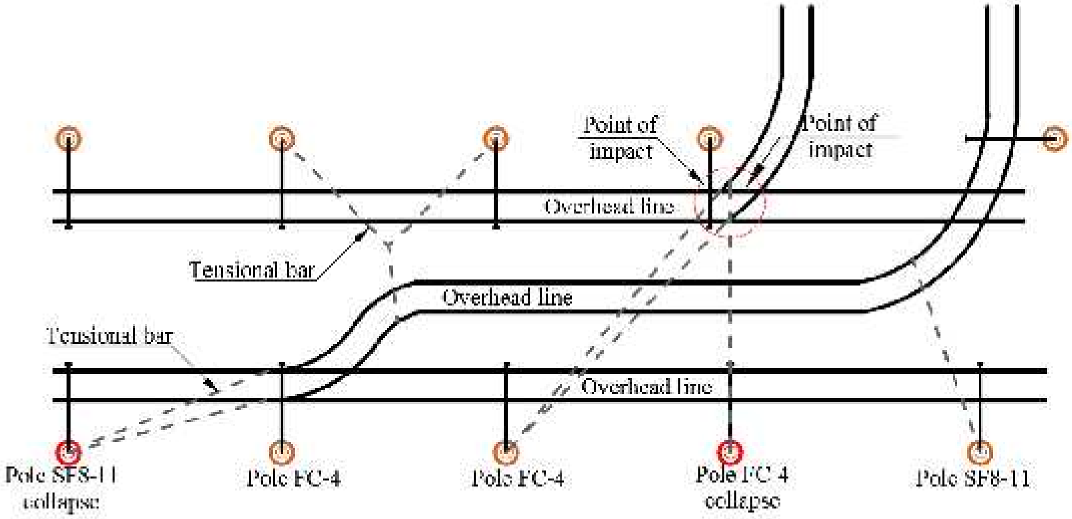

Fig. 1. *Plan to position poles of network*

prestressed longitudinal reinforcement respectively, both poles being performed by precast concrete. Practically, precast concrete poles can be manufactured by vibrate or centrifugation technique.

The internal forces in poles are influenced by their position in the transport network, so they can be in alignment, angular or terminal. The internal forces are at the bending moment and/or the torsional moment.

In this case study the local transport network is composed of precast concrete poles type SF8-11 and FC-4, with hollow section tubular with varying diameter in length, from 38.0 cm to 21.5 cm, with reinforcement in the form of casing made of 14Φ18 mm(PC52) longitudinal and rebar in the form of rings Φ6 (OB37) for SF8-11. In our second pole FC-4 type of longitudinal reinforcement is in the form of multi-strands and rebar form to hooped reinforcement [8].

The execution mark of concrete was estimated B300 equivalent C18/22.5.

2. Description of the Case Study

Investigations conducted were aimed at identifying the causes of the failure poles and the safety level in maintenance that it has.

2.1. Investigating the Causes of Degradation

Analysis of the level of degradation, which conduce to the damaged items, was performed on two components:

- Investigating technical status of the poles [4];
- Evaluation of minimum rupture force of the pole produced by the action of the trolley poles (together contact shoes).

a. Investigating technical status of the poles

Procedure of investigation and analysis were [7]:

- remarks and findings on site
- measured performed on damaged items
- information on the operating environment
- chemical laboratory determinations
- destructive measurements
- technical documentation regarding the structure of electrical transport poles.

Observations, analyses and measurements made on site on poles follow to various forms of degradation highlighting the following [7]:

-longitudinal cracks opening approximately 1-2 mm, directed by section joining of formwork, Figure 2;

Fig. 2. *Longitudinal crack after collapse*

- cracks in size and orientation uneven distributed over the length of the pole;

Fig. 3. *Random cracks*

-detaching and exfoliation of the concrete covering that the reinforcement with more pronounced manifestations in the portion of the pole bases;

- rust stains from concrete surface more pronounced in the bottom of the pole;

- unveiling reinforcements in the rupture of the pole, by highlighting the sectioning all corrosion approx. 30% of longitudinal reinforcement;

- advanced corrosion of reinforcement in longitudinal and rebar bottom of the pole;

a)

b)

a) in site *b)after collapse*

Fig. 4. *Corrosion of reinforcement pole*

- washing of concrete aggregates for the cement;

- uncontrolled practice a hole in the portion above the sidewalk for the transition of cables for public lighting;

- removing the cover closing the upper pole.

Analysis forms of manifestation for degradation existing, revealed destructive action antifreeze protection of roads agents used in road maintenance in winter, and the effect of concrete carbonation

Chemical laboratory test results Table 1

No.	Test name	Unit	Value	Limit under STAS3349/1-83
1	pH value to 20ºC	-	2.8	4.5
2	soluble chlorides	$mgCl^-/kg$	980	3000
3	free CO_2	mg CO_2/dm^3	74	90

coating of reinforcements, as a result of the action of environmental factors [3].

Laboratory tests carried out on samples taken in situ have revealed pH level to 20ºC soluble chlorides and free CO_2, Table 1, [6].

Laboratory results and the forms of degradation found, highlights chemical corrosion of concrete action by soft water (softened) of rain and snowmelt, chloride ion and carbon dioxide and electrochemical corrosion of reinforcement [5].

Determining the average depth of carbonation of concrete [5] action under the effect of CO_2 on the basis of the relation:

$$\overline{w} = \frac{150\, c\, k\, d}{f_{cd}} (t)^{1/2} \quad (1)$$

where:

f_{cd}- design value of concrete cylinder compressive strength,

c- coefficient depending on the type of cement,

k- coefficient of working conditions,

d- coefficient of influence the CO_2 and chloride ion,

t- during the action of CO_2 and/or chloride ion.

The average depth of carbonation of concrete is 2.42 cm, exceeding the coating thickness that the bars and reinforcing steel corrosion protection cancellation.

To obtain the compression strength of the concrete in poles, f_{cd}, cores were taken in situ. Interpreting laboratory results obtained on specimens extracted led to the establishment of concrete compressive strength, the value f_{cd} =2.14 N/mm^2, respectively class C16/20. Depreciation reflects the value set concrete with a strength class.

b. Evaluation Minimum Ultimate Strength of the Pole

Ultimate strength of the pole was determined from the value of the bending moment capacity in the required section respectively section located above the level of the pole fixed, foundation reported the lever arm strength tensile cable.

Ultimate strength of the pole set based on the values of bearing capacity to constitute the point of departure deducting the minimum of impact force induced in the cable fall the pole on electrical networks, knowing the geometrical characteristics and material of the cable and distance to the point.

The dynamic effect of traction and balance at cable, together with the tendency of the column to torsion were considered in the calculation through an amplification coefficient of static actions, noted c_{amp}, with values:

- c_{amp}=1.4 for pole FC-4,
- c_{amp}=1.6 for pole SF8-11.

On the basis of the geometrical and material situation of the poles in the projected [2] and the actual situation since the break, it was determined the following:

- The design resistance moment in section of fixed:
  - In project design
    M_{Rd}=45.30 kNm, for FC-4 pole,

M_{Rd}=39.40 kNm, for SF8-11 pole.

- In actual situation

M_{Rd}=24.90 kNm, for FC-4 pole,

M_{Rd}=21.70 kNm, for SF8-11 pole.

• Ultimate collapse force of the pole:

$F_{min,c}$=4.98 kN, for FC-4 pole,

$F_{min,c}$=4.34 kN, for SF8-11 pole.

By correcting these values by the coefficient c_{amp}, ultimate forces of the poles are:

$F_{min,c}$=6.97 kN, for FC-4 pole,

$F_{min,c}$=6.94 kN, for SF8-11 pole.

2.2 Evaluation of the Depreciation of the Poles Bearing Capacity of Transport Networks

Environmental operating conditions poles of the electric network contributed to the depreciation of the material properties of components in time, through the action of physical factors, mechanical and chemical, causing reduction in the bearing capacity poles in fixed section.

Analysis the degree of depreciation was conducted in two working versions:

- in specific environmental operating conditions;
- under incorrect operation.

Specific operating environment conditions are determined by the action while climate factors, aging of materials, chemical corrosion and electrochemical reinforcement of concrete. Incorrect operating conditions are the specific ones plus those due to improper operation (overload, practice random holes and unveiling reinforcements, etc.)

Resistance design of bending moments values were determined on the basis of the geometrical and material, in the design phase and in the collapse of poles.

$$R = \frac{M_{\mathrm{Re}\,ff}}{M_{Rd}} \qquad (2)$$

Assessing the level of the depreciation bearing capacity was determined as the ratio of the bending moment in time effective investigation capable of maximum bending moment and bearing capacity to design [1].

After performing calculations have resulted the following values:

• Specific environmental degradation conditions of exploitation:

R=0.3

•Operating in adverse conditions:

R=0.6

3. Conclusions

After interpreting the results obtained in this case study were obtained following conclusions:

- the state of degradation of the supporting poles of the electricity transmission network for public transport, area located in the upper third, was favoured by 40-60% this percentage thaw agents used in road maintenance during winter;
- this chloride ions lead to speedy reactions and corrosion of reinforcements substantially reducing the time of splitting reinforcements;
- insufficient of the concrete cover thickness that the reinforcement and increasing need for its more than 2.5 cm;

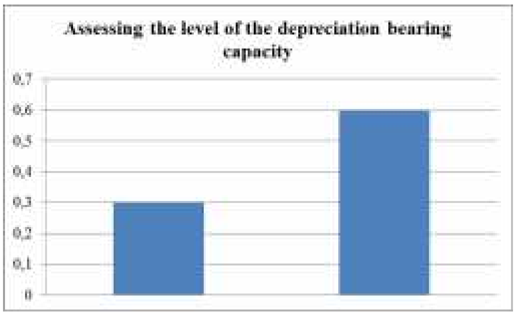

Fig. 5. *Graphical representation for assessing the level*

- improper operating conditions has reduced bearing capacity, expressed in section bending moment capable of fixing 30% increase from specific working conditions, figure 5.

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