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Title: Data on triethylenetetramine effect on steel-rebar corrosion-rate in concrete immersed in 0.5 M H_2SO_4

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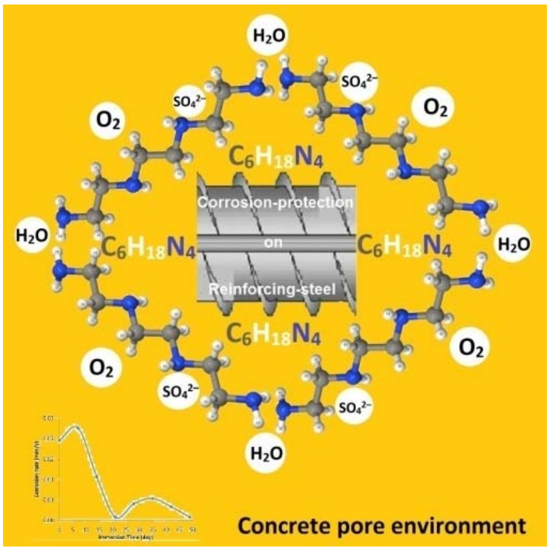
Abstract
In this article, the dataset on the effect of different triethylenetetramine (TETA: $C_6H_{18}N_4$) concentrations on the corrosion-rate of steel-rebar embedment in steel-reinforced concrete immersed in 0.5 M H_2SO_4 (for simulating industrial/microbial environment) is presented. The corrosion test-data was obtained from weekly monitoring, over seven weeks of steel-reinforced concrete immersion, using linear-polarization-resistance (LPR) measuring instrument. The dataset and its requisite analyses, as per ASTM G16—13, are presented in graphs and tables. The analyses detailed include descriptive statistics of the Normal, Gumbel and Weibull probability distribution functions (pdf's), and tests-of-fit significance by the Kolmogorov-Smirnov goodness-of-fit statistics. The detailed information from this corrosion tests dataset is useful for further research on the inhibition mechanism and effectiveness of the triethylenetetramine chemical on the corrosion-protection of reinforcing-steel material in steel-reinforced concrete designed for the industrial/microbial service-environment.

Graphical abstract



Keywords: corrosion; reinforcing-steel; steel-reinforced-concrete; triethylenetetramine; H_2SO_4

Specifications Table

Subject area	*Mechanical Engineering Science, Materials Science and Engineering, Chemical Engineering, Organic Chemistry*
Compounds	*Triethylenetetramine (TETA: $C_6H_{18}N_4$), H_2SO_4*
Data category	*Corrosion-rate by linear polarization-resistance (LPR) instrument*
Data acquisition format	*Corrosion rate monitoring using LPR Data Logger Model 1500 obtained from Metal Samples®*
Data type	*Raw, analyzed*
Procedure	*Cast steel-reinforced concrete samples having different concentrations of triethylenetetramine as admixtures were immersed in 0.5 M H_2SO_4 medium and from these, corrosion-rate by the LPR Data logging instrument was monitored at intervals over the experimental period, monitored data were then subjected to statistical analyses prescribed by ASTM G16-13*
Data accessibility	*A comprehensive dataset of corrosion-rate is provided in this article*

Rationale

Steel-reinforced concrete is the most widely used construction materials globally, due to its durability, cost and relative strength compared to other materials that could have been used for building structures and infrastructures [1-5]. However, corrosion degradation of steel-reinforced concrete, by aggressive agents in its service-environment, is a major deterioration mechanism militating against the durability and structural integrity of this construction material [5-7]. Among deleterious service-environment to steel-reinforced concrete material include the acidic sulfate environment that could ensue from reactions of SO_2 industrial effluent with atmospheric water to form acid rain, or the sulfur reducing biogenic microbial activities in sewage environments [3,8-10]. Sulfuric acid from these industrial or microbial sources attacks hydrated component of steel-reinforced concrete and corrodes the reinforcing steel embedment in the concrete [10-12]. This grossly reduces structural strength of the steel-reinforced concrete and if unchecked could lead to unprecedented failure of the structural member, which could be catastrophically injurious with attendant safety risks to life and loss of property [11,13]. Measures for avoiding these forms of calamities that could follow the corrosion-induced failure of steel-reinforced concrete structures and infrastructures constitute huge/costly financial budgets that in many countries of the world, developed and developing [11,14]. It is for these reasons that researchers and construction stakeholders are continuously engaged in search for effective solution techniques for mitigating corrosion degradation of steel-reinforced concrete by aggressive agents in its service-environment.

Among several methods, the use of corrosion inhibitors as admixture in steel-reinforced concrete is highly attractive due its relatively lower cost, high effectiveness, and ease of application that is essentially labor saving [15-18]. However, ascertaining the effectiveness of a substance on its corrosion inhibition performance on steel-reinforced concrete requires experimental data-monitoring and requisite analyses of the measured data for detailing and consequently drawing inference on the usability of that substance as corrosion inhibitor [1,19]. Findings from research works are supporting use of organic chemicals as inhibitors of metallic corrosion [20-22]. Reasons for this is due to the affinities of the lone-pairs and π-electron ligands in organic chemicals that are known to exhibit affinity for the iron in steel-rebar to which they could be adsorbed and thereby protect the rebar from corrosion attacks [20,22]. In addition to this physicochemical behavior of organic inhibitors, amines are known to act as pore blockers to concrete, through reversed hydrophobic propensity, which precludes ingress of aggressive agent, including acidic sulfate, into the concrete, thus protecting both the concrete and its embedded steel-rebar from corrosion attacks [23-24].

Triethylenetetramine is an organic (amine) chemical that had been successfully employed for inhibiting metallic corrosion in acidic and neutral chloride environments in reported works [22,25-27]. However, there is paucity of study on the use of triethylenetetramine for inhibiting steel-rebar corrosion in acidic sulfate environment. Authors of this article are not aware of other research works that had detailed data on triethylenetetramine corrosion-rate effect on steel-reinforced concrete. Therefore, this article presents corrosion-rate dataset and its requisite rendering to statistical analyses, as prescribed by ASTM G16-13 [28] and the literature for efficiently interpreting/validating inherently stochastic corrosion data [29-30], from triethylenetetramine effect on steel-rebar in concrete immersed in 0.5 M H_2SO_4.

Procedure

Steel-reinforced concrete were freshly cast and during casting, different concentrations of triethylenetetramine (Molecular Weight 146.24, CAS No. 112-24-3 from Loba Chemie (via Oxford Laboratory), India), of > 99% purity, were employed as admixture as prescribed in ASTM C192 / 192M-16a [31] in the concrete sample mixing, and into the casting of which the steel-rebar was centrally embedded. The varying concentration of triethylenetetramine employed was initiated from 0.0365 M $C_6H_{18}N_4$, actually, 0.036471 M $C_6H_{18}N_4$ corrected to four decimal places, and was then incremented in this $C_6H_{18}N_4$ concentration until attaining 0.1824 M $C_6H_{18}N_4$. The samples of steel-reinforced concretes were then partially immersed in plastic containers of 0.5 M H_2SO_4 test-solution [32-33]. From these experimental setups, corrosion-rate was monitored, and recorded, right from the 0th day and then in seven days interval for the next seven weeks. For this corrosion-rate monitoring, linear-polarization-resistance measuring equipment, the LPR Data Logger, Model MS1500L was used [32-34]. This direct readout corrosion monitoring equipment utilizes 3-electrode system for which Ag/AgCl SCE from Direct-ION® constitutes the reference, a brass plate constitutes the auxiliary electrode and the steel-rebar is employed as the working electrode [35-36].

For heeding recommendation of ASTM G16-13 [28], for the efficient detailing/validation of inherently stochastic corrosion test-data, each corrosion-rate dataset, i.e. from each sample of steel-reinforced concrete sample having different concentration of triethylenetetramine, was subjected to the fittings of statistical distributions [37-40]. These statistical distribution fitting model for this data article include the Normal, the Gumbel and the Weibull probability distribution, and for each of these distributions, the maximum likelihood estimation technique was employed for detailing parameter estimations from the corrosion-rate datasets [38-39,41-42]. In furtherance to these, compatibility of each corrosion-rate dataset, i.e. from each steel-reinforced concrete sample having triethylenetetramine admixture, to each of the probability distributions was tested using the Kolmogorov-Smirnov goodness-of-fit statistics at α = 0.05 level of statistical significance [42-48]. Also detailed in this data article are the reliability estimations of the analyzed descriptive central tendency of corrosion-rate ensuing form the probability distribution modeling [37,39,49].

Data, value and validation

The raw datasets of corrosion-rate from the experimental monitoring of steel-rebar corrosion in the steel-reinforced concrete, having varying triethylenetetramine concentration as admixtures, are presented in graphical plots in Figure 1. This figure is divided to plots of datasets for each of the varying concentrations of triethylenetetramine, and which are requisitely detailed in each of the plots in the figure.

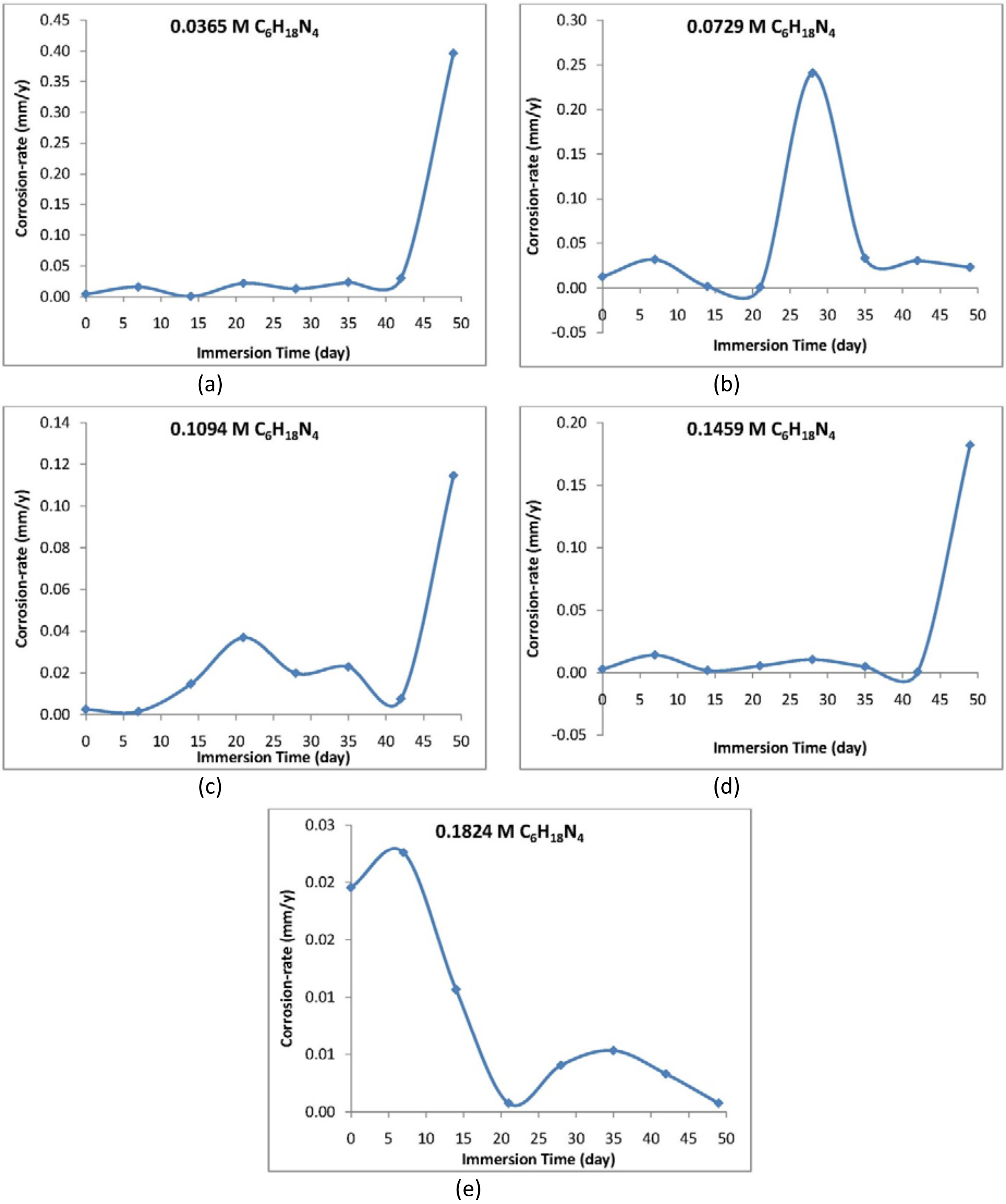


Figure 1: Graphical plots of the corrosion-rate test-data measured from the use of different concentrations of triethylenetetramine as admixture in steel-reinforced concrete samples immersed in 0.5 M H_2SO_4 medium (a) Sample with 0.0365 M $C_6H_{18}N_4$ admixture (b) Sample with 0.0729 M $C_6H_{18}N_4$ admixture (c) Sample with 0.1094 M $C_6H_{18}N_4$ admixture (d) Sample with 0.1459 M $C_6H_{18}N_4$ admixture, and (e) Sample with 0.1824 M $C_6H_{18}N_4$ admixture.

The values of these presented data include:

- Corrosion-rate monitoring, through polarization resistance, is a useful technique for ascertaining performance of a substance on the inhibition of metallic corrosion, i.e. whether the substance mitigates or promotes corrosion, in a corrosive test-system [50].
- The representation of the corrosion-rate, from the varying concentration usage of triethylenetetramine admixture in steel-reinforced concrete samples, in graphical plots exhibit the usefulness for lending important insights into:
    - The effectiveness or otherwise of the different triethylenetetramine concentrations at mitigating corrosion;
    - Periods when the corrosion mitigation effectiveness breakdown and/or whether such breakdown of corrosion mitigation was recoverable/non-recovered in the steel-reinforced concrete samples, within the experimental monitoring period for the presented datasets;
    - The reducing ranges of corrosion-rate, observable from the ordinates in Figure 1, as the triethylenetetramine admixture concentration in the steel-reinforced concrete samples increases.
- The datasets of corrosion rate from this study could be employed in further research, especially, that which could be combined with forms of steel-reinforced concrete control samples for detailing anticorrosion efficiency as well as the prevalent corrosion-protection mechanism of triethylenetetramine on steel-rebar in steel-reinforced concrete for the industrial/microbial service-environment [51-52].

The descriptive statistics, the mean (μ) and standard deviation (σ), estimations from the corrosion-rate datasets of triethylenetetramine effects on steel-reinforced concrete samples are presented in Table 1 for the estimated values using the Normal, the Gumbel and the Weibull distribution models. The table also contains the test-of-fit significance estimated as the Kolmogorov-Smirnov (goodness-of-fit) probability values, K-S *p*-value, as well as the validation decision (significant or not significant) that could be drawn from the fitting of each dataset to the probability distribution models. The decision of "not significant" indicates that the dataset does not come from the fitting probability distribution, while the decision of "significant" implies the modeled dataset distributed like the fitting probability distribution.

Table 1: Descriptive statistics and goodness-of-fit analyses of datasets of corrosion-rate for the article

Statistical Parameters		$C_6H_{18}N_4$ Admixture Concentration (M)				
		0.0365	**0.0729**	**0.1094**	**0.1459**	**0.1824**
Normal pdf	μ	0.0631	0.0469	0.0276	0.0277	0.0084
	σ	0.1350	0.0794	0.0370	0.0625	0.0085
	K-S *p*-value	0.0367	0.0601	0.3901	0.0440	0.5495
	Decision	**Not Significant**	**Significant**	**Significant**	**Not Significant**	**Significant**
Gumbel pdf	μ	0.0557	0.0439	0.0272	0.0243	0.0087
	σ	0.0768	0.0511	0.0285	0.0355	0.0086
	K-S *p*-value	0.0498	0.1237	0.6624	0.0712	0.7531
	Decision	**Not Significant**	**Significant**	**Significant**	**Significant**	**Significant**

Statistical Parameters		$C_6H_{18}N_4$ Admixture Concentration (M)				
		0.0365	**0.0729**	**0.1094**	**0.1459**	**0.1824**
Weibull pdf	μ	0.0776	0.0581	0.0318	0.0331	0.0093
	σ	0.1835	0.1126	0.0472	0.0825	0.0117
	K-S *p*-value	0.4958	0.6222	0.9827	0.6525	0.9891
	Decision	**Significant**	**Significant**	**Significant**	**Significant**	**Significant**

Presented in Figure 3 are the graphical reliability plots of the descriptive statistics of the Normal, Gumbel and Weibull distribution modeling of corrosion-rate datasets from the steel-reinforced concrete samples having different triethylenetetramine admixture concentrations. For the reason that the reliability of the mean by the Normal distribution is monotonically = 0.5 (or 50%) and of the Gumbel is monotonically = 0.5704 (or 57.04%), irrespective of the value of the mean, the reliabilities for these distribution models are presented in linear plots within Figure 2. In contrast to these, the reliability of the Weibull distribution model varies as the value of the mean changes, thus, reliabilities estimated using the Weibull model are presented in its varying form in Figure 2.

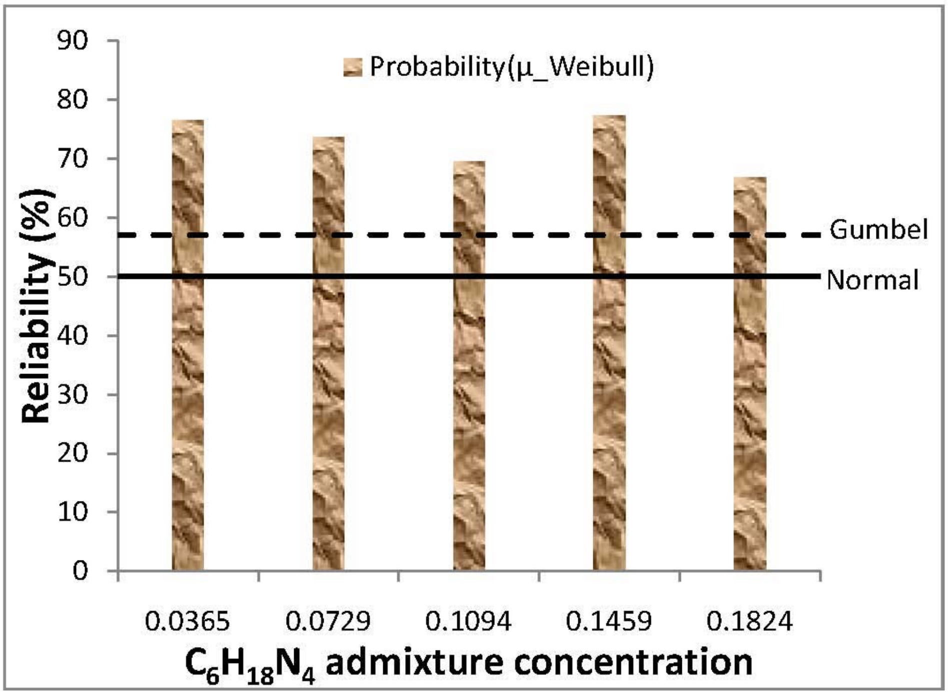


Figure 2: Reliability of the descriptive statistics models of corrosion-rate datasets from steel-reinforced concretes having triethylenetetramine admixture concentrations.

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