Stress-Strain, Creep, and Temperature Dependency of ADSS (All Dielectric Self Supporting) Cable's Sag & Tension Calculation

Abstract

This paper will provide an understanding of the inherent physical properties of ADSS cables as it relates to an accurate determination of sag; both initial and final, bare cable and loaded conditions. It's been common in the industry to calculate sag & tension charts for ADSS cables without taking into consideration the influence of creep, coefficient of thermal expansion (CTE), and the difference between the initial and final modulus. Therefore, the sag was provided only as a function of span, weight, and tension, just at the initial state (no final state), and independent of temperature. Another misunderstanding is the confusion between "final state" (after creep) and "loading condition"(wind+ice) which are 2 different cases. Following thorough and repeated AFL stress-strain and creep tests, this paper will show that ADSS cable has both an "initial state" and a "final state", **each one of them** having an "unloaded" (bare cable) and a "loaded" (ice and/or wind) case, and it's sag & tension are a function of creep and CTE. Additionally, the results of AFL's work were ultimately implemented in Alcoa sag & tension software: SAG10.

Catenary Curve Analytic Method

In Fig.1, is presented an ADSS cable element under the outer and inner stresses, with a length, on the curve $y_{(x)}$, given by formula:

$l=\int_{x_1}^{x_2}\sqrt{1+y'^{2}_{(x)}}\cdot dx$ (1); yields: $\frac{dl}{dx}=\sqrt{1+y'^{2}_{(x)}}$ (2)

Also, the equilibrium equations results in:

$H_1=H_2=H$ (3) ; $V_1-V_2=dV=w\cdot dl$ (4)

considering rel. (2), the derivative of rel. (4) yields:

$\frac{dV}{dx}=w\cdot\frac{dl}{dx}=w\cdot\sqrt{1+y'^{2}_{(x)}}$ (5); also, the slope in any point of the catenary curve is defined as the first derivative of the function $y_{(x)}$ of the curve:

$V=H\cdot\tan\varphi=H\cdot\frac{dy}{dx}=H\cdot y'$ (6); yields:

$\frac{dV}{dx}=H\cdot\frac{dy'}{dx}$ (7) ; and: $\frac{dV}{dx}=H\cdot y''$ (8) ; using rel. (5) and (8), results: $H\cdot y''=w\cdot\sqrt{1+y'^2}$ (9) , and then:

$\frac{y''}{\sqrt{1+y'^2}}=\frac{w}{H}$ (10); integrating rel. (10), results:

Paper published in IWCS Proceedings, Nov.15-18, 1999, pages 605-613. Reprinted, with permission.

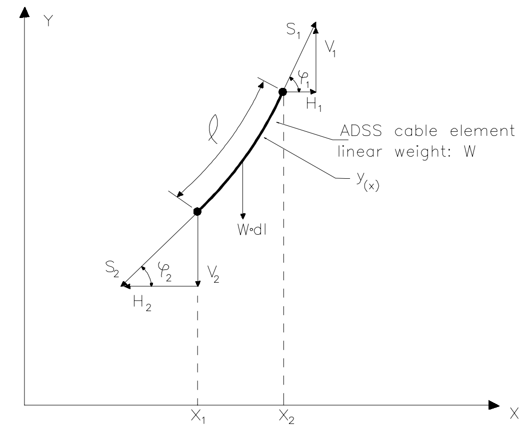


Fig.1 – Catenary Curve Analytic Method

$\ln\left(y'+\sqrt{1+y'^2}\right)=\frac{w}{H}\cdot x+k_1$ (11), followed by:

$y'+\sqrt{1+y'^2}=e^{\left(\frac{w}{H}\cdot x+k_1\right)}$ (12), which has as solution:

$y'=\sinh\left(\frac{w}{H}\cdot x+k_1\right)$ (13) ; integrating rel.(13) results:

$y=\frac{H}{w}\cdot\cosh\left(\frac{w}{H}\cdot x+k_1\right)+k_2$ (14); for x=0 results:

$y=\frac{H}{w}$ (15) and : $y'=0$ (16), so : $k_1=k_2=0$ (17),

resulting the catenary curve equation: $\boxed{y=a\cdot\cosh\frac{x}{a}}$ (18)

where the catenary constant is: $\boxed{a=\frac{H}{w}}$ (19) and:

$y'=\sinh\frac{x}{a}$ (20). In Fig.2 the designations are: S= span length; B=S/2= half span length (assuming level supports); D= sag at mid-span; H= tension at the lowest point on the catenary (horizontal tension) - only for leveled span case, it's in the center of the span; T= tension in cable at structure (maximum tension); P= average tension in cable; L/2=arc length of half-span; l= arc length from origin to point where coordinates are (x,y); a (C respectively) = distance of origin (of support respectively) from directrix of catenary; t= angle of tangent at support with directrix; k= angle of tangent at point (x,y); w= resultant weight per unit length of cable; ε = cable strain (arc elongation in percent of span).

At limit, see Fig.2, for: $x=\frac{S}{2}=B$, rel. (18) becomes:

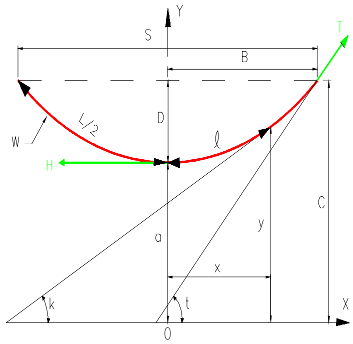


Fig. 2 – Leveled Span Case

$C = a \cdot \cosh\frac{B}{a}$ (21); where: $\cosh\frac{x}{a} = 0.5 \cdot \left(e^{\frac{x}{a}} + e^{-\frac{x}{a}}\right)$ (22)

and: $\sinh\frac{x}{a} = 0.5 \cdot \left(e^{\frac{x}{a}} - e^{-\frac{x}{a}}\right)$ (23) , so:

$l = \int_0^x \sqrt{1 + y'^2} \cdot dx = \int_0^x \sqrt{1 + \sinh^2\frac{x}{a}} \cdot dx$ (24), or:

$l = \int_0^x \cosh\frac{x}{a} \cdot dx$ (25), resulting from rel. (25) the cable length equation: $\boxed{l = a \cdot \sinh\frac{x}{a}}$ (26). At limit, for: $x = \frac{S}{2} = B$, rel.(26) becomes: $\boxed{\frac{L}{2} = a \cdot \sinh\frac{B}{a}}$ (27). Also, using rel.(21), the sag equation is determined:

$\boxed{D = C - a = a \cdot \left(\cosh\frac{B}{a} - 1\right)}$ (28). At limit, rel. (19) becomes:

$\boxed{C = \frac{T}{w}}$ (29). From (29) and (21):

$\boxed{T = w \cdot C = w \cdot a \cdot \cosh\frac{B}{a}}$ (30) , so: $\boxed{T = H \cdot \cosh\frac{B}{a}}$ (31) and:

$\boxed{P = \frac{H+T}{2} = 0.5 \cdot H \cdot \left(1 + \cosh\frac{B}{a}\right)}$ (32). Cable strain is defined as arc elongation in percent of span: $\boxed{\varepsilon = \left(\frac{L}{S} - 1\right) \cdot 100}$ (33).

Taylor's series for cosh yields:

$$\cosh\frac{B}{a} = 1 + \frac{1}{2!} \cdot \left(\frac{B}{a}\right)^2 + \frac{1}{4!} \cdot \left(\frac{B}{a}\right)^4 + \ldots \quad (34)$$

|-----2 terms------|
|--------------3 terms--------------|

"2 terms" formula for rel. (28) results in:

$$D = a \cdot \left[1 + \frac{1}{2!} \cdot \left(\frac{B}{a}\right)^2 - 1\right] = \frac{1}{2} \cdot \frac{B^2}{a} = \frac{1}{2} \cdot \frac{\left(\frac{S}{2}\right)^2}{\frac{H}{w}} \quad (35)$$

yielding the "parabola" equation: $\boxed{D = \frac{w \cdot S^2}{8 \cdot H}}$ (36)

"3 terms" formula for rel. (28) results in:

$$D = a \cdot \left[1 + \frac{1}{2!} \cdot \left(\frac{B}{a}\right)^2 + \frac{1}{4!} \cdot \left(\frac{B}{a}\right)^4 - 1\right] \quad (37)$$

which, using B=S/2 and rel. (19), yields the "approximate catenary" formula : $\boxed{D = \frac{w \cdot S^2}{8 \cdot H} + \frac{w^3 \cdot S^4}{384 \cdot H^3}}$ (38)

For sags bigger than 5% of the span, rel. (36),"parabola", gives erroneous results, while rel. (38) gives a more accurate solution, the exact solution being given by rel.28.

Complete example for ADSS "Transmission"

The following variables, for the <u>same span</u>, have the <u>same values</u> for <u>any material</u> (ACSR, AAC, EHS, ADSS, etc.) as long as they <u>respect</u> the <u>catenary equations</u>.
Span: S=1400 [ft]; w=1 [lbs/ft]= constant value; H=9038 [lbs]=assumed value; a=H/w=9038 [ft]; B=S/2=700 [ft];

$C = a \cdot \cosh\frac{B}{a} = 9065.12$ [ft]; D=C-a=27.12 [ft];

$L = 2 \cdot a \cdot \sinh\frac{B}{a} = 1401.4$ [ft] ; $\varepsilon = \left(\frac{L}{S} - 1\right) \cdot 100 = 0.1$ [%];

$\frac{D}{S} \cdot 100 = 1.9372$ [%]; $T = w \cdot C = 9065$ [lbs];

$\frac{T}{w} = 9065$ [lbs] ; $P = \frac{H+T}{2} = 9052$ [lbs]; $\frac{P}{w} = 9052$ [lbs]

<u>ADSS Characteristics</u>:

d=0.906 [in]; $A = \frac{\pi}{4} \cdot d^2 = 0.6447$ [in^2]; w_c=0.277 [lbs/ft];

RBS=14186 [lbs]; MRCL=8064 [lbs];

CTE= $\alpha = 3.32 \cdot 10^{-6} \left[1/{}^0F\right]$;

modulus: initial: E_i=1250.9 [kpsi]; final: E_f=1359.6 [kpsi];
10 years Creep: E_c=1025.3 [kpsi]

<u>Loading Curve Type:</u>
B= ADSS w/o ice or wind ("bare unloaded" cable):
resultant weight: w_r=w_c=0.277 [lbs/ft]
H= ADSS plus heavy loading: according to NESC:
Regular ice density: $\gamma_{ice} = 57$ [lbs/ft^3];

Ice radial thickness: t=0.5 [in]; Temperature: $\theta = 0$ [^0F];
Wind velocity: V_w=40 [mph]; NESC factor: k=0.3;
Wind pressure: $P_w = 0.0025 \cdot V_w^2$ =4 [psf];
Ice weight:

$$w_{ice} = \frac{\pi}{4} \cdot \frac{(d + 2 \cdot t)^2 - d^2}{144} \cdot \gamma_{ice} = 0.875 \quad \text{[lbs/ft]}$$

Wind force: $w_w = \frac{p_w \cdot (d + 2 \cdot t)}{12} = 0.635$ [lbs/ft]

Resultant weight:

$$w_r = \sqrt{(w_c + w_{ice})^2 + w_w^2} + k = 1.615 \quad \text{[lbs/ft]}$$

Loading Curve Type	Resultant weight: w_r [lbs/ft]	Cross Sectional area:A [in^2]	S=1400 [ft] Stress [psi] $\sigma = \frac{P}{A} = \left(\frac{P}{w}\right) \cdot \frac{w_r}{A}$

B	0.277	0.6447	$(9052)\cdot\frac{0.277}{0.6447}=3889$
H	1.615	0.6447	$(9052)\cdot\frac{1.615}{0.6447}=22676$

Tensions Limits:

a) Maximum tension at 0° F under heavy loading not to exceed 51.35% RBS: MWT=51.35%RBS=7285 [lbs]

$$\sigma_{MWT} = \frac{MWT}{A} = 11300[psi]$$

Note: MWT (max. working tension) was selected **less than MRCL**=8064 [lbs] = 56.84% RBS, in order for this ADSS cable **to cope with limit c)** presented below.

b) Initial tension (when installed) at 60°F w/o ice or wind ("bare unloaded" cable) not to exceed 35% RBS:

$T_{EDS_i} = 35\%RBS = 4965$ [lbs]; $\sigma_{EDS_i} = \frac{T_{EDS_i}}{A} = 7700[psi]$

c) Final tension at 60°F w/o ice or wind ("bare unloaded" cable) not to exceed 25% RBS:

$T_{EDSf} = 25\%RBS = 3546$ [lbs];

$$\sigma_{EDS_f} = \frac{T_{EDS_f}}{A} = 5500[psi]$$

Catenary Table:

strain	%sag	Span S = 1400 [ft]					
ε	D/S·100	D	T/w	H/w	P/w	σ	[psi]
[%]	[%]	[ft]	[ft]	[ft]	[ft]	B	H
0.025	0.9686	13.56	18088	18074	18081	7769	45294
0.030	1.0608	14.85	16520	16506	16513	7095	41366
0.040	1.2249	17.15	14308	14291	14300	6144	35822
0.050	1.3695	19.17	12800	12781	12791	5496	32042
0.075	1.6775	23.48	10459	10436	10448	4489	26173
0.100	1.9372	27.12	9065	9038	9052	3889	22676
0.150	2.3729	33.22	7413	7380	7397	3178	18530
0.200	2.7401	38.36	6430	6392	6412	2755	16063
0.250	3.0642	42.90	5761	5718	5740	2466	14379
0.300	3.3576	47.00	5267	5219	5243	2253	13134
0.350	3.6273	50.78	4883	4833	4858	2087	12169
0.400	3.8788	54.30	4575	4521	4548	1954	11393
0.450	4.1144	57.60	4320	4263	4292	1844	10752
0.500	4.3377	60.73	4105	4045	4075	1751	10208
0.550	4.5502	63.70	3920	3856	3888	1670	9740
0.600	4.7533	66.55	3759	3692	3725	1600	9331
0.650	4.9483	69.28	3618	3549	3584	1540	8978
0.700	5.1360	71.90	3492	3420	3456	1485	8657
0.750	5.3172	74.44	3378	3304	3341	1435	8369
0.800	5.4925	76.90	3276	3199	3238	1391	8111
0.850	5.6636	79.29	3182	3103	3142	1350	7871
0.900	5.8278	81.59	3098	3017	3058	1314	7660
0.950	5.9886	83.84	3020	2936	2978	1288	7460
1.000	6.1458	86.03	2948	2862	2905	1248	7277
1	2	3	4	5	6	7	8

Columns:

1 and 2: they are the same for any span, any material.

3, 4, 5, 6: they are the same, for the <u>same span</u>, for any material: ACSR, AAC, EHS, ADSS, etc.

7 and 8: they are different, from one material to another: ACSR, AAC, EHS, ADSS, etc.

This catenary table is transformed in a Preliminary Sag-Tension Graph, in Fig.7. This graph has 2 "y" axis: left side: stress [psi]: σ_B and σ_H; B-bare cable; H-heavy load, and right side: sag: D [ft]. Also, it has 2 "x" axis: strain: ε [%] (arc elongation in percent of span) and temperature: θ [°F].

Stress-Strain Tests

ADSS cable stress-strain tests performed in AFL lab show (see Fig.3) that they fit a straight line, characterized by a polynomial function of 1st degree, whereas metallic cables (conductors, OPT-GW, etc.) are characterized by a polynomial function of 4th degree (5 coefficients). From all the tests performed, results show, that in general, the ratio between the initial modulus: E_i (slope of the "charge" curve) and the final modulus: E_f (slope of the "discharge" curve) is between (0.911..0.95), and the permanent stretch: ε_p (also referred to as "set"), at the "discharge", is between (0.05…0.08)%, depending on the ADSS design. In the particular case of the cable design we analyze (see Fig.4), $E_i=0.92\cdot E_f$; ε_p=0.08 %.

Creep Tests

According to the ADSS cable standard[1], the creep test must be performed at a constant tension equal with 50%· MRCL for 1000 hours at room temperature of 60 ° F. In general, for ADSS cables: MRCL=[0.45…0.60]·RBS therefore the test is done at T=[0.225…0.30]· RBS=ct. (see Fig.3). Considering a "nominal" value of MRCL=50%· RBS, the "default" constant tension for the test would be: T=25%· RBS. Creep test, on the cable design we analyze, was done at a constant tension: T=50%· MRCL=28%· RBS, because for this cable: MRCL=56%· RBS (see Fig.4). The values were recorded after every hour, see Fig.5-"CreepTest: Polynomial Curve" and Fig.6-"Creep Test: Logarithmic Curve". The strain after 1 hour, defined as "initial creep", was 42.69 [μin/in], after 1000 hours (41.6 days) was 314.10 [μin/in]. So "recorded creep" during the test, defined as strain at 1000 [h] minus strain at 1 [h], is 271.41[μin/in]. The extrapolated value after 87360 hours (10 years, 364 days/year) is 1142.69 [μin/in]. Therefore, the **"10 years creep"**, which is defined as strain at 87360 [h] minus strain at 1 [h], is 1100 [μin/in] =**0.11** [%]. Other creep tests performed on other ADSS cable designs showed "10 years creep" value in the same range. The curves on the stress-strain and tension-strain graphs are identical, the only difference is that on the ordinates (y) axis, when going from tension [lbs] to stress [psi], there is a division by the cross-sectional area of the cable: A [in²]. The values on the strain (x) axis remain the same. Now, going into the stress-strain graph (Fig.4) at a tension (stress) equal with the value for which the creep test was performed: T=50%· MRCL (σ=50%· MRCL/A), a parallel to the x axis, will intersect the " initial modulus" curve in a point of abscise: $0.5\cdot\ \varepsilon_{MRCL}$, and from that point, going horizontally, adding the "10 years creep " value of 0.11 [%] we'll obtain the point corresponding to that tension, for which the creep test was performed, on the "10 years creep " curve. Drawing a line from origin through that point results the slope (the modulus) for the "10 years creep":E_c. Generally, from all the tests performed, for a large variety of ADSS cables designs, results that: E_c=[0.804…0.819]· E_i ; E_c=[0.732…0.778] · E_f (see Fig.3). For the example we analyze: $E_c=0.819\cdot E_i$; $E_c=0.753\cdot E_f$. (see Fig.4). Always, for any ADSS design, the relation between the 3 moduli is: $E_f > E_i > E_c$.

Coefficient of Thermal Expansion

The values for CTE (designated here as α) were determined by the individual material properties in a

mixture formula: $\alpha = \sum_{i=1}^{n} \alpha_i E_i A_i \,/ \sum_{i=1}^{n} E_i A_i$ (39) where: α_i, A_i, Ei are the CTE, cross-sectional area and modulus of each one of the "i" elements in the ADSS construction: aramid yarn, outer jacket, inner jacket, buffer tubes, FRP, tapes, filler, etc. Generally, for the great majority of ADSS cable design, the influence of CTE is smaller than that of creep. Due to the fact that the aramid yarn is the only element with a negative α =-$5 \cdot 10^{-6}$ [1/^{o}C]=-$2.77 \cdot 10^{-6}$ [1/^{o}F], while the rest of the elements have a positive α, designs with a low number of aramid yarn ends (typically for short spans) will yield differences in sags, due to temperature, greater than designs with high number of aramid yarn ends. As a comparison, to see how big is the impact of number of aramid yarn used, typical values of ADSS CTE, designs with low number of aramid yarn ends, could be in a range: $2 \cdot 10^{-6}$ [1/^{o}F], up to $9 \cdot 10^{-6}$ [1/^{o}F], therefore close to Aluminum CTE=$12.8 \cdot 10^{-6}$ [1/^{o}F], and sometimes even greater than Steel CTE=$6.4 \cdot 10^{-6}$ [1/^{o}F], while for high numbers of aramid ends (over 80 up to 120), could go down **100 times**, even **1000 times**: $2 \cdot 10^{-8}$ [1/^{o}F],or: $8 \cdot 10^{-9}$ [1/^{o}F] and in that moment
it's influence on sag is negligible.

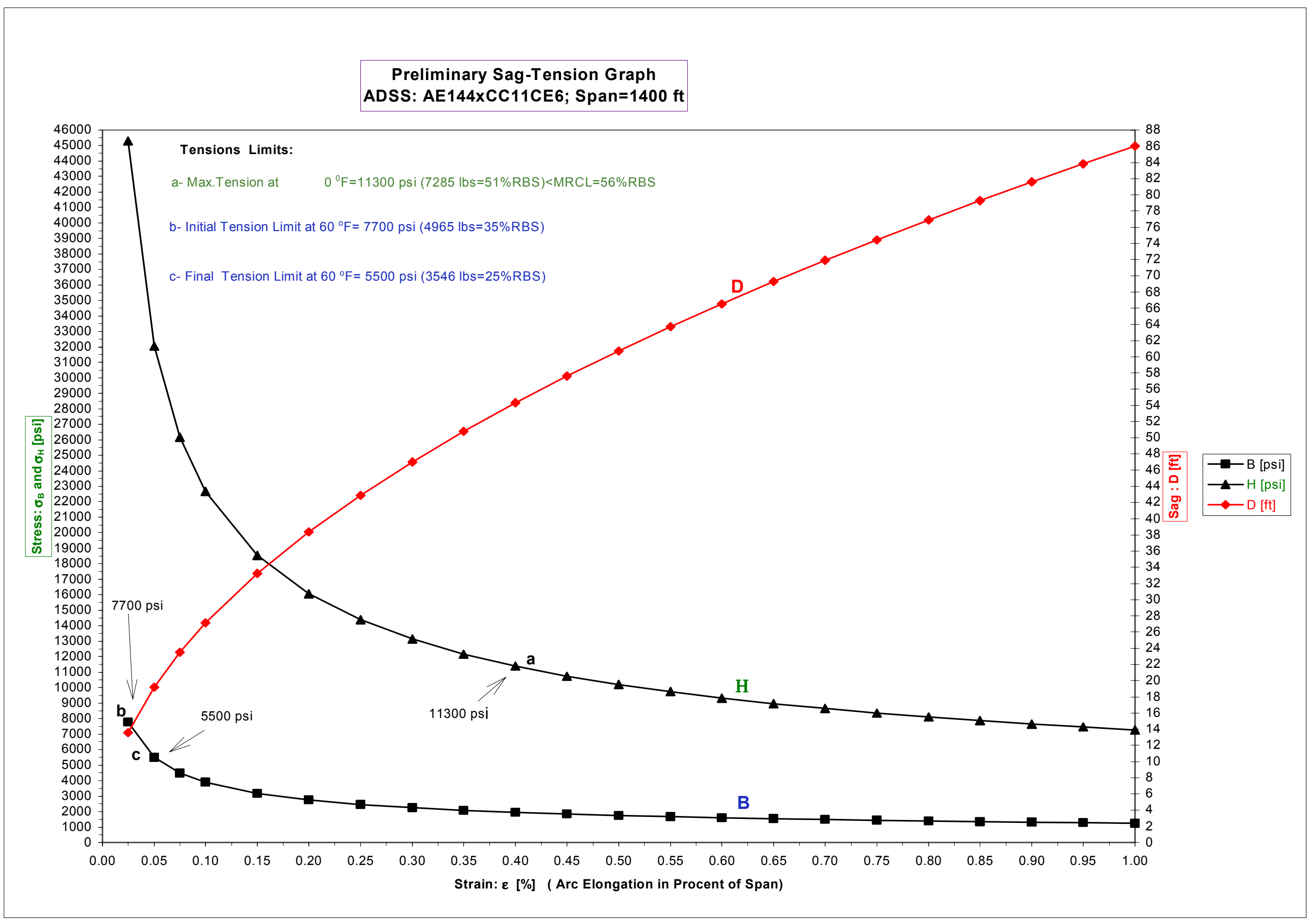


Fig. 7- Preliminary Sag-Tension Graph

Sag-Tension Charts

The well known general equation of change of state:

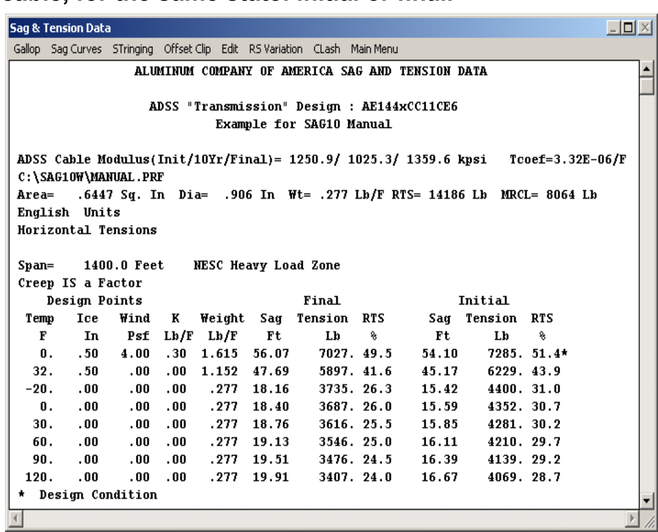
$$\frac{w_2 \cdot S^2}{24 \cdot H_2^2} - \frac{w_1 \cdot S^2}{24 \cdot H_1^2} = \frac{H_2 - H_1}{A \cdot E} + \alpha \cdot (\theta_2 - \theta_1) \quad (40)$$

shows only that the change in slack=change in elastic elongation+change in thermal elongation, it does not include the change in plastic elongation (the creep). So, it's true only if the 2 states of the cable are in the same stage: **initial or final**, so if you look at sag charts (Fig.12 & Fig.13), it will allow someone to go only **vertically** from one case to another case, but it does not allow to go **horizontally**: same case, same temperature, same loading conditions, from initial stage to final stage, due to creep. A simplistic way of solving this issue, which is still used in some European countries, is the following: the creep influence is considered to be equivalent with an "off-set temperature": "θ_{creep}" given by the ratio: (conductor 10 yrs. creep-initial elongation)/ CTE. But it's not an exact method, because it means you just calculate an INITIAL sag&tension chart, and then the FINAL sag&tension chart is **identical** with the initial chart, the only thing is that you **move (shift) the initial chart to align it** with the **new corresponding temperature**: final sag at temperature: "θ" is equal with the initial temperature at "$\theta + \theta_{creep}$". The most accurate and exact solution is the graphic method.

Following this method, which is an Alcoa method[2, 3] , the stress-strain graph (Fig.4) of this particular ADSS cable is superimposed on the ADSS preliminary sag-tension graph (Fig.7), so their abscissas coincide and the whole system of curves from Fig.4 are **translated** to the **left, parallel with the "x" axis**, up until the initial curve, noted "2", in Fig. 4 (and also in Fig.8) intersects the curve H on the **index mark=11300 psi (tension limit a])** the imposed maximum tension at 0^oF under heavy load. We have imposed MWT=51%RBS, slightly less than MRCL=56%RBS, to be sure that neither tension limits b] or c] will be exceeded. Therefore, tension limit **a]** is the **governing condition**. The superposed graphs then appear in Fig.8. The resultant initial sag @ 0^oF under heavy loading (54.10 ft.) is found vertically above point a] on curve D. The initial tension @ 60^oF, bare cable=6750 psi (4352 lbs) is found at the intersection of curve 2 with curve B, and the corresponding sag (15.59 ft) is on curve D. The final stress-strain curve 3a, which is the curve after loading to maximum tension (MWT=51%RBS), at 0^0F, is drawn from point a], which is the intersection point of curves 2 and H, parallel to curve 3, which is the final stress-strain curve after loading to MRCL=56%RBS, at 0^oF. Now, the final tension at 0^oF, after heavy loading =6440 psi (4151 lbs) is found where curve 3a intersects curve B. The corresponding sag (16.35 ft) is found vertically on curve D. The next operation is to determine whether the final sag after 10 years creep at 60^oF will exceed the final sag after heavy loading at 0^oF. Before moving the stress-strain graph from its present position, the location of 0^oF on it's temperature scale is marked on Fig.8 as reference point R. The temperature off-set to the right at 60^oF (Fig.8) in %strain is equal with: $\alpha \cdot 60^oF \cdot 100=0.01992$ [%] (41) where: $\alpha=3.32 \cdot 10^{-6}$ [$1/^oF$] is this ADSS CTE. Therefore, the stress-strain graph is moved to the right with 0.01992 [%] (Fig.8) until 60^oF on the temperature scale coincide with reference point R (Fig.9). The initial tension at 60^oF=6530 psi (4210 lbs) is found at the intersection of curve 2 with curve B, and the corresponding sag (16.11ft) is found vertically on curve D. The final stress-strain curve 3 b, under heavy loading, after creep for 10 years at 60^oF, is drawn from the intersection point of curves 4 and B, parallel to curve 3. The final tension at 60^oF , after creep for 10 years=5500 psi (3546 lbs) is located at the intersection of curve 3b (or curve 4) with curve B . The corresponding sag (19.13 ft) is found vertically on curve D. **Since the final sag at 60^oF after creep for 10 years=19.13 ft (Fig.9) exceeds the final sag at 0^oF after heavy loading =16.35 ft (Fig.8), creep is the governing case, and SAG10 output will give a flag: "CREEP IS A FACTOR". SAG10 will print only the final chart after creep (no more the final chart after heavy load) (see Fig.12).** The final sag and tension at 0^oF must now be corrected using the revised stress-strain curve. For this purpose the temperature axis will have an off-set of 0.01992 [%] to left (Fig.9) to get values at 0^oF. Therefore, the stress-strain graph is moved to left (Fig.9), until 0^oF on the temperature scale coincide with reference point R (Fig.10). The **corrected** final tension at 0^oF**, bare cable**, (**after creep for 10 years at 60^oF**)=5720 psi (3687 lbs) is found at the intersection between curves 3b and B. The corresponding final sag (18.40 ft.) is found vertically on curve D. The final tension at 0^oF, **under heavy loading**, (**after 10 years creep at 60^oF**)=10900 psi (7027 lbs) is found at the intersection between curves 3b and H. It's corresponding **resultant** final sag (56.07 ft) it's on curve D (Fig.10). **The maximum temperature of the ADSS cable will be the maximum possible ambient temperature, let's say 120^oF (49^oC)**. Only conductors can reach higher values, let's say 167^oF (75^oC), or 212^oF (100^oC), but that is due to their continuous current rating, which does not exist for ADSS cables. Thus, for 120^oF, the temperature off-set to the right (Fig.10) to get values at 120^oF, in %strain is: $\alpha \cdot 120^oF \cdot 100=0.03984$ [%]. Therefore, the stress-strain graph is moved to right with this value (Fig.10) until 120^oF on the temperature scale coincide with reference point R (Fig.11). The initial tension at 120^oF=6311 psi (4069 lbs) is found at the intersection of curve 2 with curve B, and corresponding sag (16.67 ft) is on curve D. The final tension at 120^oF (**after creep for 10 years at 60^oF**)=5285 psi (3407 lbs) is found at the intersection of curve 3b (or 4) and curve B, and corresponding sag (19.91 ft) is on curve D (Fig.11).

Conclusions

Using the ADSS characteristics from page 2 as input data, the output in SAG10, is presented in Fig.12. As a note, if for a different ADSS design and different span and loading conditions, **the permanent elongation after heavy loading would have been bigger than the one after 10 years creep**, and there are such cases, the SAG10 flag would have been "CREEP IS NOT A FACTOR", and the final sag printed in SAG10 would have been the sag after heavy load, which would have been bigger than the one after 10 years creep. **The influence of the creep on the ADSS cable sag** is different from one design to another, **but always significant**: the difference between the final and the initial sag could be **0.5 ft up to 1.5 ft** in a span range of **200 to 600 ft**, and **1.5 to 3.0 ft** in a span range of **600 to 1400 ft**, under **NESC Heavy** loading case. For river crossing spans over **1800 ft** the difference could be **3 to 3.8 ft. For creep influence, always one has a HORIZONTAL comparison: going from initial chart to final chart, same loading case, same temperature.** The influence of the **coefficient of thermal expansion** on the ADSS cable sag **is smaller than that of creep**: changes in sag due to temperatures ranging from **-20^oF to 120^oF** would yield **0.5 ft up to 1.75 ft** for low aramid yarn counts applications (**significant values**), and could go down to just 0.01 ft (**negligible value**) for those designs with maximum number of aramid yarns**. For CTE influence, always one has a VERTICAL comparison: going from minimum temperature to maximum temperature, bare cable, for the same state: initial or final.**


Sag & Tension Data

Gallop Sag Curves STringing Offset Clip Edit RS Variation CLash Main Menu

ALUMINUM COMPANY OF AMERICA SAG AND TENSION DATA

ADSS "Transmission" Design : AE144xCC11CE6
Example for SAG10 Manual

ADSS Cable Modulus(Init/10Yr/Final)= 1250.9/ 1025.3/ 1359.6 kpsi Tcoef=3.32E-06/F
C:\SAG10W\MANUAL.PRF
Area= .6447 Sq. In Dia= .906 In Wt= .277 Lb/F RTS= 14186 Lb MRCL= 8064 Lb
English Units
Horizontal Tensions

Span= 1400.0 Feet NESC Heavy Load Zone
Creep IS a Factor

Design Points					Final			Initial		
Temp F	Ice In	Wind Psf	K Lb/F	Weight Lb/F	Sag Ft	Tension Lb	RTS %	Sag Ft	Tension Lb	RTS %
0.	.50	4.00	.30	1.615	56.07	7027.	49.5	54.10	7285.	51.4*
32.	.50	.00	.00	1.152	47.69	5897.	41.6	45.17	6229.	43.9
-20.	.00	.00	.00	.277	18.16	3735.	26.3	15.42	4400.	31.0
0.	.00	.00	.00	.277	18.40	3687.	26.0	15.59	4352.	30.7
30.	.00	.00	.00	.277	18.76	3616.	25.5	15.85	4281.	30.2
60.	.00	.00	.00	.277	19.13	3546.	25.0	16.11	4210.	29.7
90.	.00	.00	.00	.277	19.51	3476.	24.5	16.39	4139.	29.2
120.	.00	.00	.00	.277	19.91	3407.	24.0	16.67	4069.	28.7

* Design Condition

Fig.12-SAG10 Output for this particular ADSS design

References

1. IEEE 1222P- Standard for All Dielectric Self-Supporting Fiber Optic Cable (ADSS) for use on Overhead Utility Lines - Draft, April 1995
2. Aluminum Electrical Conductor Handbook , chapter 5- third edition, 1989
3. Alcoa Handbook, Section 8:"Graphic Method for Sag Tension Calculation for ASCR and Other Conductors"-1970