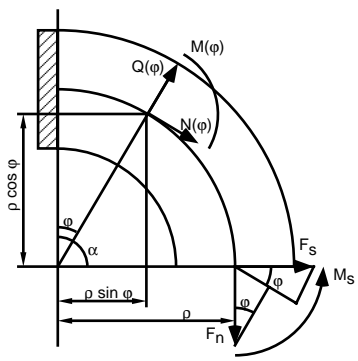
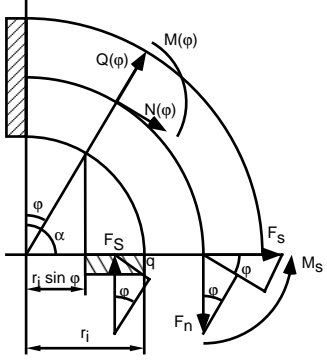
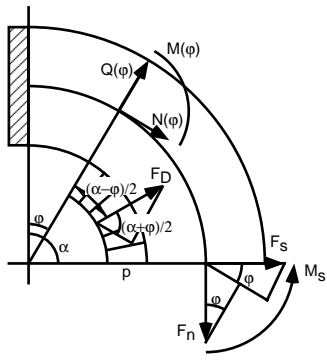
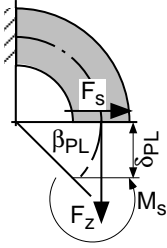
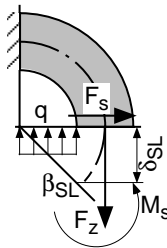
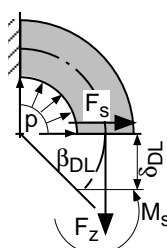


Anhang: Formelsammlung zur Berechnung von Bolzen-Lasche-Verbindungen bei elastischen Beanspruchungen

A1 Schnittgrößen für die unterschiedlichen Belastungstypen

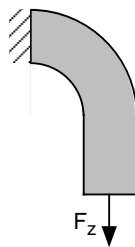
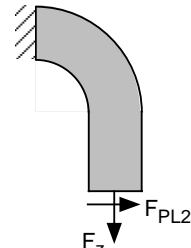
Lastfall	Schnittgrößen
	<p>Punktlast</p> $N_{PL}(\varphi) = F_n \sin \varphi + F_q \cos \varphi$ $Q_{PL}(\varphi) = F_q \sin \varphi - F_n \cos \varphi$ $M_{PL}(\varphi) = F_n \rho (1 - \sin \varphi) - F_q (l + \rho \cos \varphi) - M_b$
	<p>Streckenlast</p> $N_{SL}(\varphi) = F_n \sin^2 \varphi + F_q \cos \varphi$ $Q_{SL}(\varphi) = (F_q - F_n \cos \varphi) \sin \varphi$ $M_{SL}(\varphi) = \left(1 - \frac{r_i}{2\rho}\right) F_n \rho \cos^2 \varphi - F_q (l + \rho \cos \varphi) - M_b$
	<p>Drucklast</p> $N_{DL}(\varphi) = F_n \left(\frac{2 \sin^2 \frac{\alpha - \varphi}{2}}{\sin \alpha} - \sin \varphi \right) + F_q \cos \varphi$ $Q_{DL}(\varphi) = F_n \left(\frac{2 \sin \frac{\alpha - \varphi}{2} \cos \frac{\alpha - \varphi}{2}}{\sin \alpha} - \cos \varphi \right) + F_q \sin \varphi$ $M_{DL}(\varphi) = F_n \rho \left(1 - \frac{2 \sin^2 \frac{\alpha - \varphi}{2}}{\sin \alpha} - \sin \varphi \right) - F_q (l + \rho \cos \varphi) - M_b$

A2 Verformungsgleichungen für die unterschiedlichen Lastfälle nach Bild 4.1

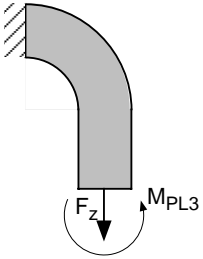
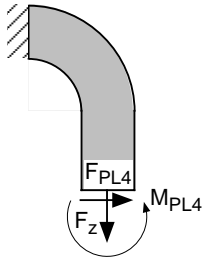
Lastfall	Verformungen
<p>Punktlast</p> 	$\beta_{PL}(\varphi) = \frac{F_z \rho [1 - \varphi(1 + \kappa) - \cos \varphi] + F_s \rho \sin \varphi + M_s \varphi(1 + \kappa)}{A_L E \kappa r}$ $\delta_{PL}(\varphi) = \beta_{PL}(\varphi) \rho \cos \varphi + \frac{F_z \rho(1 - 2 \sin \alpha - \cos^2 \alpha) + F_s \rho(\alpha + \sin \alpha \cos \alpha) + 2M_s \sin \alpha}{2A_L E \kappa}$
<p>Streckenlast</p> 	$\beta_{SL}(\varphi) = F_n \frac{r_i(\varphi + \cos \varphi \sin \varphi)(1 + \kappa) - 2\rho[\varphi(1 + 2\kappa) + \cos \varphi \sin \varphi]}{4A_L E \kappa \rho} + \frac{F_s \frac{\rho \sin \varphi}{A_L E \kappa \rho} + M_s \frac{\varphi(1 + \kappa)}{A_L E \kappa \rho}}{A_L E \kappa \rho}$ $\delta_{SL}(\varphi) = \beta_{SL}(\varphi) \rho \cos \varphi + F_n \frac{\sin \varphi(r_i - 2\rho)(2 + \cos^2 \varphi)}{6A_L E \kappa} + \frac{F_s \frac{\rho(\varphi + \cos \varphi \sin \varphi)}{2A_L E \kappa} + M_s \frac{\sin \varphi}{A_L E \kappa}}{A_L E \kappa}$
<p>Drucklast</p> 	$\beta_{DL}(\varphi) = \frac{F_n \rho(\varphi - \sin \varphi \varphi(1 + \kappa) - \cos \varphi \sin \varphi) + F_s \rho \sin^2 \varphi + M_s \varphi \sin \varphi}{A_L E \kappa \rho \sin \varphi}$ $\delta_{DL}(\varphi) = \beta_{DL}(\varphi) \rho \cos \varphi + F_n \rho \frac{4(1 - \cos \varphi)(1 - \sin \varphi) - \sin \varphi \sin 2\varphi}{4A_L E \kappa \sin \varphi} + \frac{F_s \rho \frac{\sin \varphi(1 - \cos 2\varphi)}{4A_L E \kappa \sin \varphi} + M_s \frac{\sin \varphi(1 - \cos 2\varphi)}{A_L E \kappa \sin \varphi}}{A_L E \kappa \sin \varphi}$

A3 Lagerreaktionen für unterschiedliche Fesselung nach Bild 4.2

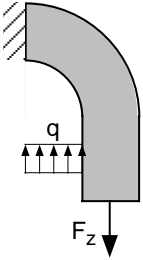
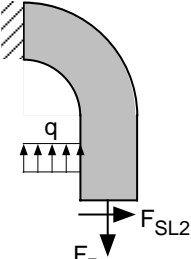
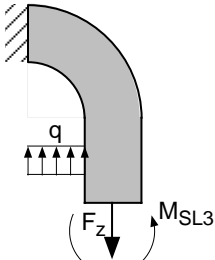
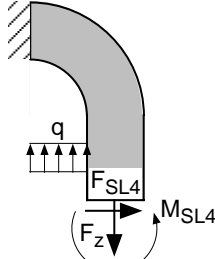
A 3.1 Punktlast nach Bild 4.1 und unterschiedliche Lagerung nach Bild 4.2

Skizze	Fesselungsbezeichnung und Schnittgrößen
	<p><i>Typ 1: Enden frei beweglich</i></p> $F_{PL1} = 0$ $M_{PL1} = 0$
	<p><i>Typ 2: Enden verdrehbar, nicht verschieblich</i></p> $F_{PL2} = 3F_z J \rho \frac{\rho\{2 \cos \alpha[\alpha(1 + \kappa) - 1] + 3 \cos^2 \alpha + 2 \sin \alpha - 1\} + 2l[\alpha(1 + \kappa) + \cos \alpha - 1]}{3J \left[\rho^2(\alpha + 3 \cos \alpha \sin \alpha) + 2\rho l[\alpha(1 + \kappa) \cos \alpha + 2 \sin \alpha] + 2l^2 \alpha(1 + \kappa) \right] + 2A_L \kappa \rho l^3}$ $M_{PL2} = 0$

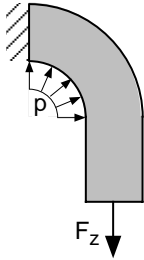
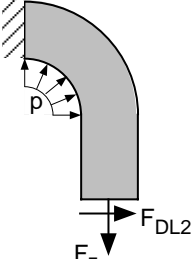
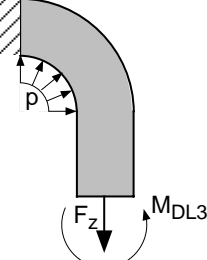
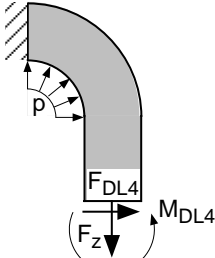
A3.1 Punktlast nach Bild 4.1 und unterschiedliche Lagerung nach Bild 4.2 (Fortsetzung)

Skizze	Fesselungsbezeichnung und Schnittgrößen
	<p><i>Typ 3: Enden verschieblich, nicht verdrehbar</i></p> $F_{PL3} = 0$ $M_{PL3} = F_z J \rho \frac{\alpha(1+\kappa) + \cos \alpha - 1}{J \alpha(1+\kappa) + A_L \kappa \rho l}$
	<p><i>Typ 4: Enden eingespannt</i></p> $F_{PL4} = 6F_n J r \frac{J\{\alpha(1+\kappa)(\cos^2 \alpha - 1) + 2\sin(1 - \cos \alpha)\} + A_L l \kappa \left\{ l[\alpha(1+\kappa) + \cos \alpha - 1] + \rho \left[\begin{array}{l} 2\cos \alpha [\alpha(1+\kappa) - 1] + \\ +3\cos^2 \alpha + 2\sin \alpha - 1 \end{array} \right] \right\}}{6J^2 \rho [\alpha(\alpha + \cos \alpha \sin \alpha)(1+\kappa) - 2\sin^2 \alpha] + 2A_L J \kappa l \left\{ \begin{array}{l} 2\alpha^2(1+\kappa) + 3l\rho[\alpha \cos \alpha(1+\kappa) + 2\sin \alpha] + \\ +3\rho^2(\alpha + 3\cos \alpha \sin \alpha) \end{array} \right\} + A_L^2 \kappa^2 l^4 \rho}$ $M_{PL3} = F_z J \rho \frac{6J \left\{ \begin{array}{l} l[\alpha(\cos^2 \alpha - 1)(1+\kappa) + 2\sin \alpha(1 - \cos \alpha)] + \\ +\rho \left[\begin{array}{l} \alpha[1 - (1+\kappa)(\alpha + \cos \alpha \sin \alpha) - \cos \alpha] - \\ -\sin \alpha(1 - \cos \alpha - 2\sin \alpha) \end{array} \right] \end{array} \right\} + A_L l^2 \left\{ \begin{array}{l} 2\kappa l[\alpha(1+\kappa) + \cos \alpha - 1] + \\ +3\kappa \rho \left[\begin{array}{l} 2\cos \alpha [\alpha(1+\kappa) - 1] + \\ +3\cos^2 \alpha + 2\sin \alpha - 1 \end{array} \right] \end{array} \right\}}{6J^2 \rho [\alpha(\alpha + \cos \alpha \sin \alpha)(1+\kappa) - 2\sin^2 \alpha] + 2J A_L \kappa l \left\{ \begin{array}{l} 2\alpha^2(1+\kappa) + 3l\rho[\alpha \cos \alpha(1+\kappa) + 2\sin \alpha] + \\ +3\rho^2(\alpha + 3\cos \alpha \sin \alpha) \end{array} \right\} + A_L^2 \kappa^2 l^4 \rho}$

A 3.2: Streckenlast nach Bild 4.1 und unterschiedliche Lagerung nach Bild 4.2

Skizze	Fesselungsbezeichnung und Schnittgrößen
	<p><i>Typ 1: Enden frei</i></p> $F_{SL1} = 0$ $M_{SL1} = 0$
	<p><i>Typ 2: Enden verdrehbar, nicht verschieblich</i></p> $6\rho l[\alpha(1+2\kappa) + \cos\alpha \sin\alpha] -$ $-3r_i(\alpha + \cos\alpha \sin\alpha)(1+\kappa) +$ $+2\rho^2[3\alpha \cos\alpha(1+2\kappa) + \sin\alpha(4+5\cos^2\alpha)] -$ $F_{SL2} = F_n I_y \frac{-\rho r_i \{3\alpha \cos\alpha(1+\kappa) + \sin\alpha[4 + \cos^2\alpha(5+3\kappa)]\}}{6I_y \left\{ \begin{aligned} &2\alpha^2(1+\kappa) + 2\rho l[\cos\alpha(1+\kappa) + 2\sin\alpha] + \\ &\quad + \rho^2(\alpha + 3\cos\alpha \sin\alpha) \end{aligned} \right\} +}$ $+4A_L \kappa l^3 \rho$ $M_{SL2} = 0$
	<p><i>Typ 3: Enden verschieblich, nicht verdrehbar</i></p> $F_{SL3} = 0$ $M_{SL3} = F_n I_y \frac{2\rho[\alpha(1+2\kappa) + \cos\alpha \sin\alpha] - r_i(\alpha + \cos\alpha \sin\alpha)(1+\kappa)}{4[I_y \alpha(1+\kappa) + A_L \kappa l \rho]}$
	<p><i>Typ 34: Enden eingespannt</i></p> <p style="text-align: center;">keine geschlossene Lösung</p>

A 3.3: Drucklast nach Bild 4.1 und unterschiedliche Lagerung nach Bild 4.2

Skizze	Fesselungsbezeichnung und Schnittgrößen
	<p><i>Typ 1: Enden frei</i></p> $F_{DL1} = 0$ $M_{DL1} = 0$
	<p><i>Typ 2: Enden verdrehbar, nicht verschieblich</i></p> $F_{DL2} = \frac{3F_z J \rho}{\sin \alpha} \frac{4l[\sin \alpha \alpha(1+\kappa) + \cos \alpha \sin \alpha - \alpha] + \rho \left[4\cos \alpha \sin \alpha \alpha(1+\kappa) - 2\alpha \cos \alpha + \sin \alpha (\cos 2\alpha + 4 - 3) \right]}{J \left[12l^2 \alpha(1+\kappa) + 12\rho l [\alpha(1+\kappa) \cos \alpha + 2\sin \alpha] + \rho^2 (6\alpha + 12\cos \alpha \sin \alpha + 3\sin 2\alpha) \right] + 4A_L \kappa \rho l^3}$ $M_{DL2} = 0$
	<p><i>Typ 3: Enden verschieblich, nicht verdrehbar</i></p> $F_{DL3} = 0$ $M_{DL3} = \frac{F_z J \rho \sin \alpha [\alpha(1+\kappa) + \cos \alpha] - \alpha}{\sin \alpha J \alpha(1+\kappa) + A \kappa \rho s}$
	<p><i>Typ 34: Enden eingespannt</i></p> <p>keine geschlossene Lösung</p>