



ADVIESBUREAU
HAGEMAN

Tanden

Ophangwapening detailleren

20 jaar later

René Braam - COBc congres - Den Haag – 6 november 2025

Advisering op het gebied van constructies voor gebouwen en civiele werken

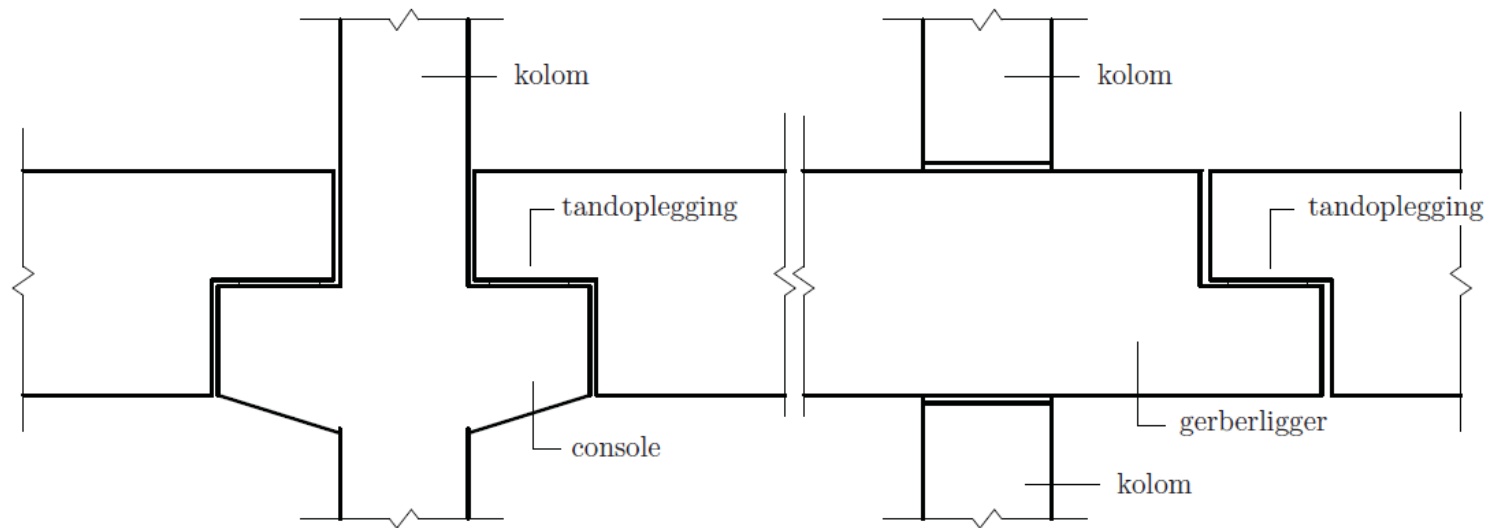
Tandoplegging - Ophangwapening detailleren

- Inleiding
- Experimenten TU/e (1)
- Experimenten TU/e (2)
- Experimenten Stuttgart
- Experimenten TU/e i.s.m. Lincon
- Analyse proefresultaten
- Aanbevelingen



Inleiding

Tanden in de praktijk

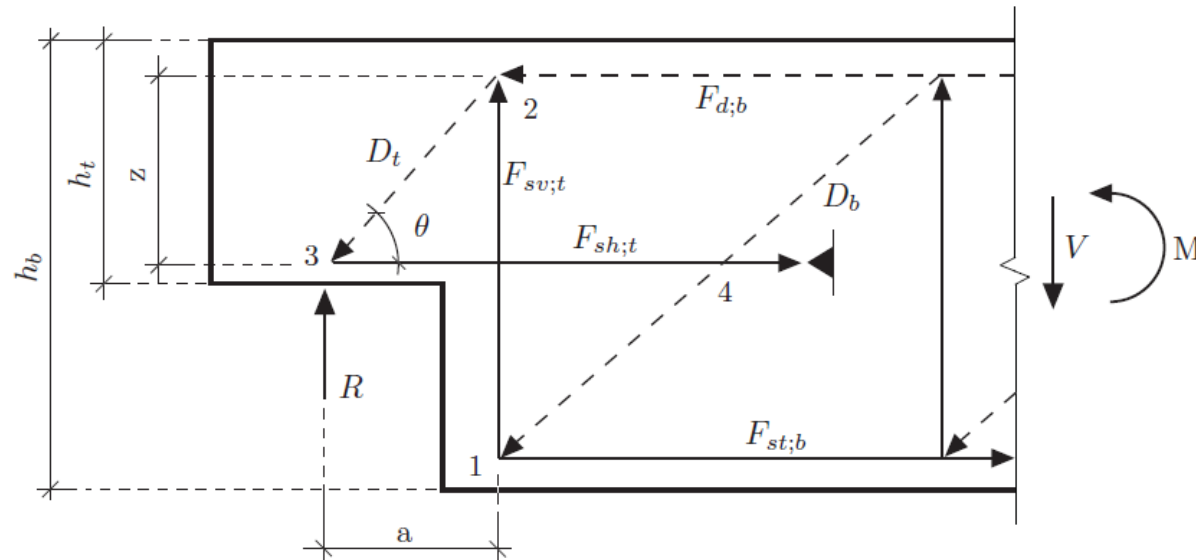


Houwen, TU/e, 2008



Inleiding

Vereenvoudigd staafwerkmodel voor de tandoplegging



--- → druk

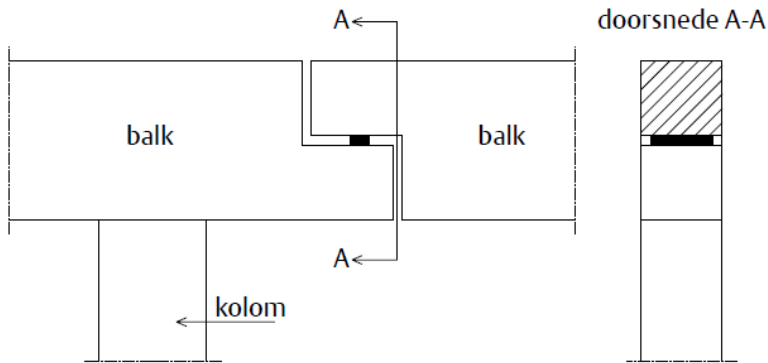
— → trek

Houwen, TU/e, 2008;
uit: Leonhardt/Mönnig, Vorlesungen über
Massivbau, 1977

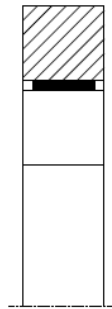


Inleiding

Kleinman (2006): Nokken met die Tanden

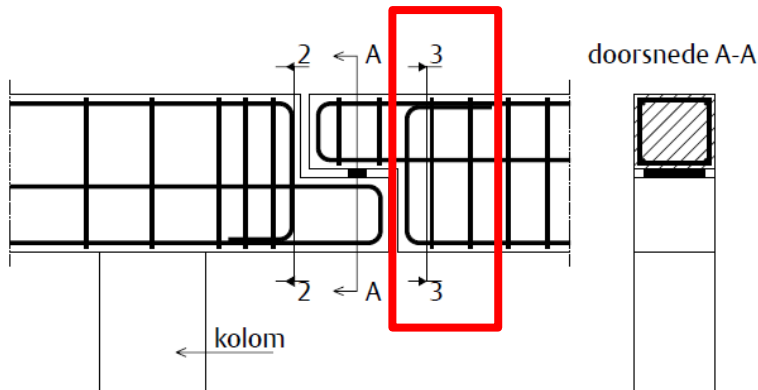


doorsnede A-A

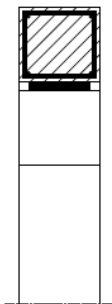


Kan de ophangwapening de functie van een starre ondersteuning vervullen?

Gedraagt de tandoplegging zich als een console?



doorsnede A-A

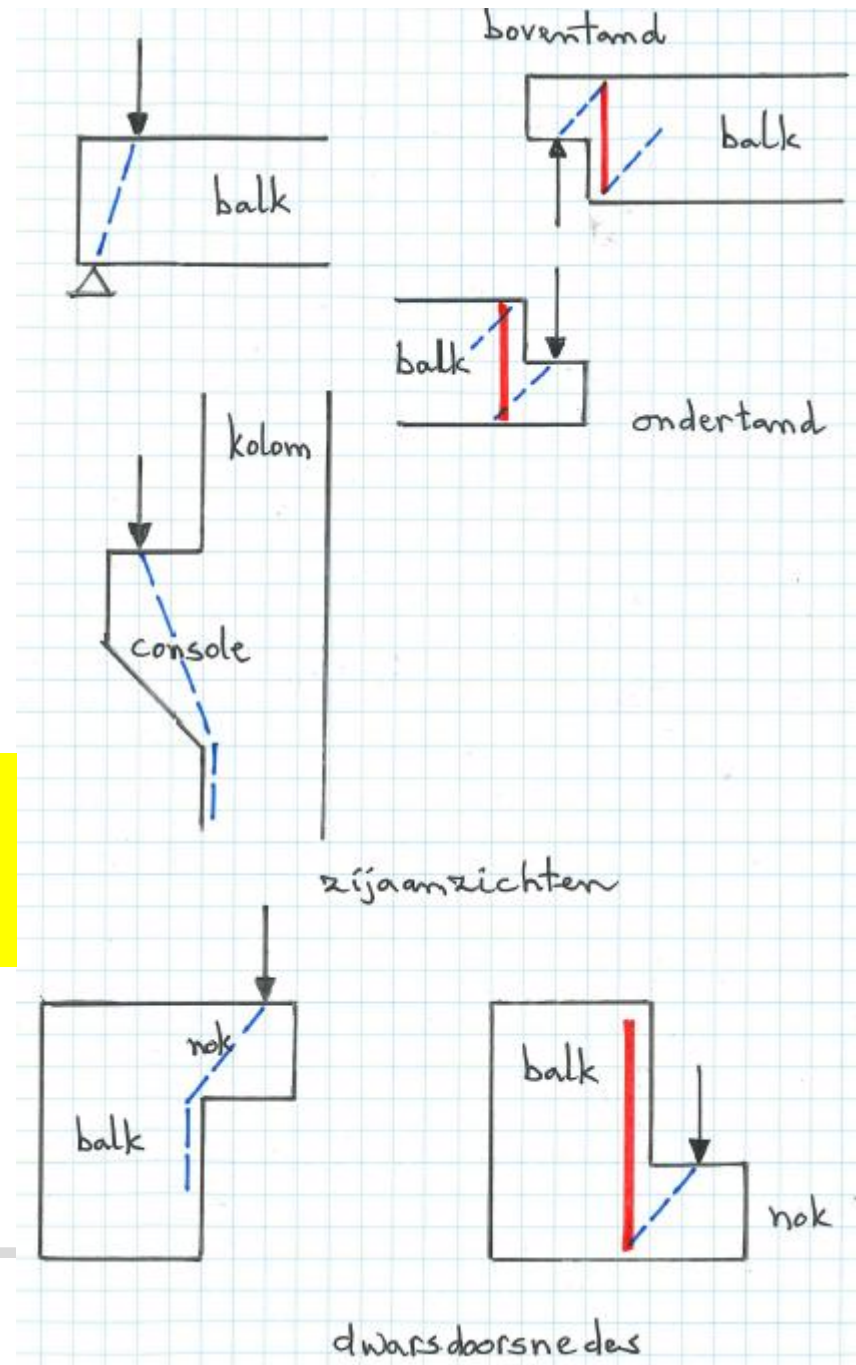


Kleinman e.a., Cement 2006 - 2010

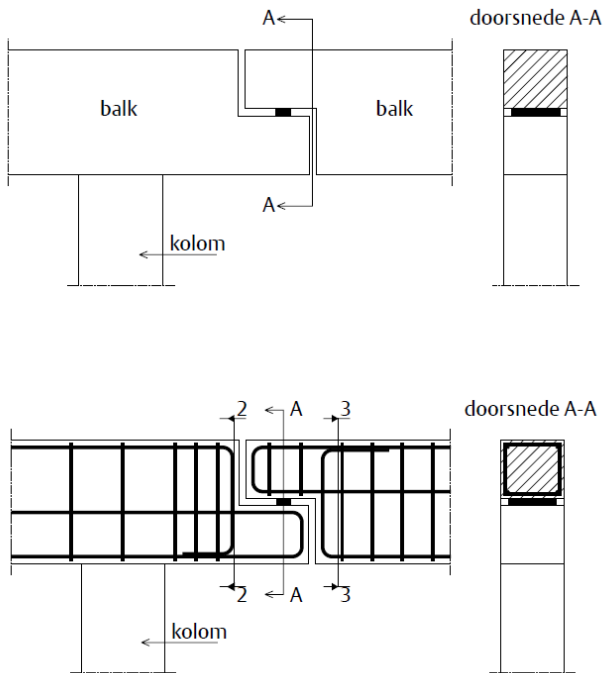
Inleiding

Directe (blauw)
en
indirecte (rood)
lastafdracht

Heeft de detaillering van de ophangwapening invloed op het bezwijkgedrag en de weerstand?

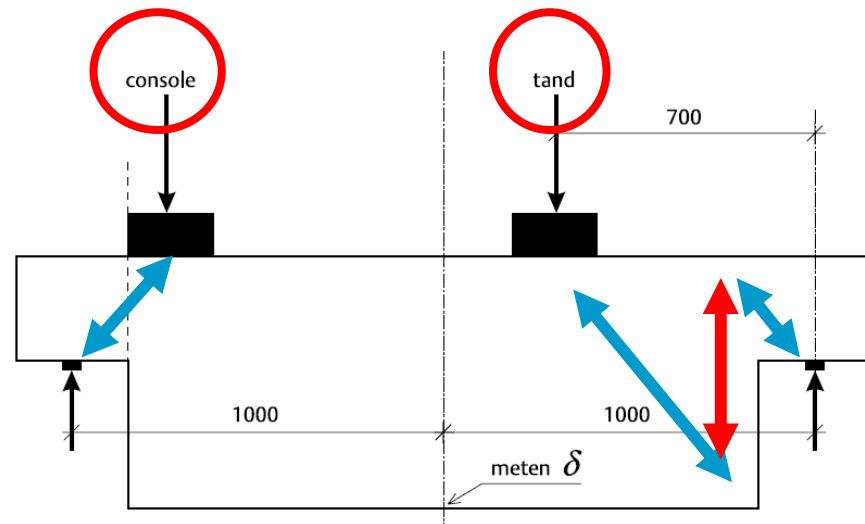


Experimenten TU/e (1)

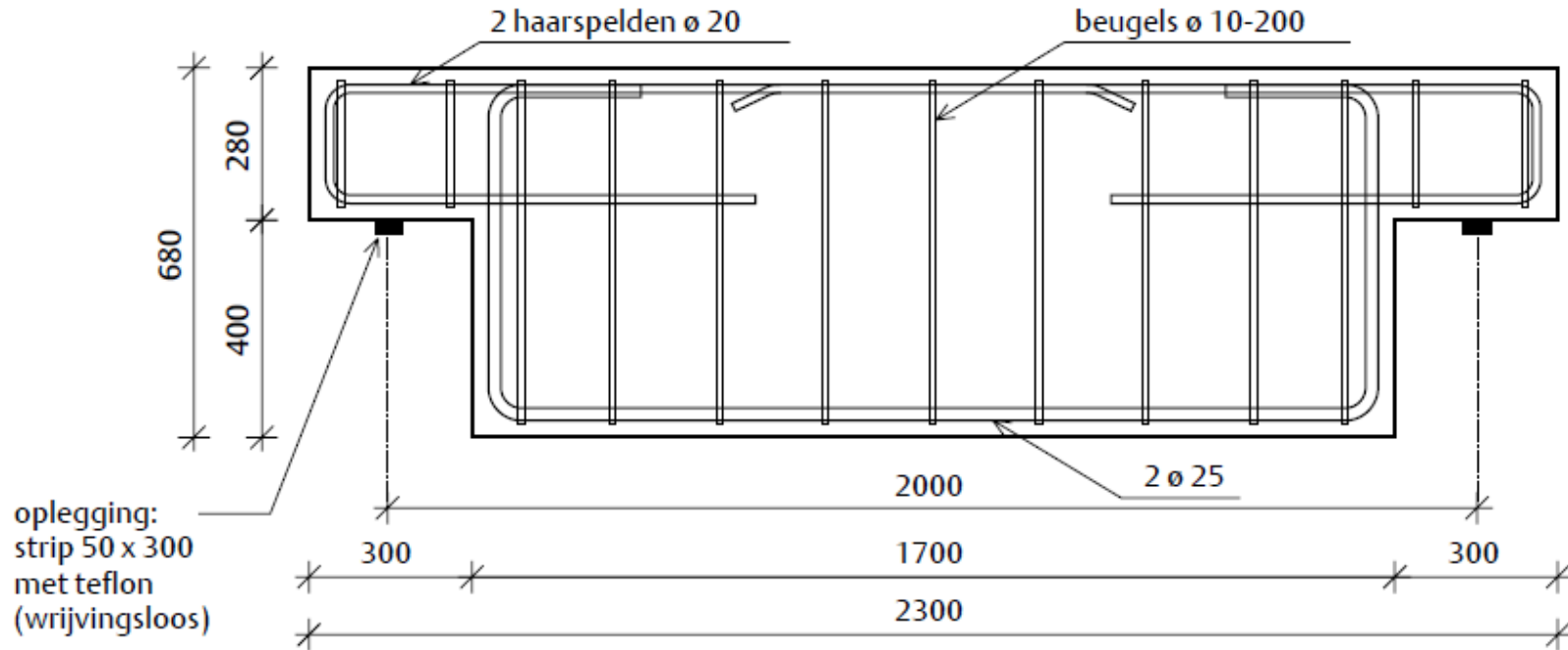


directe lastafdracht

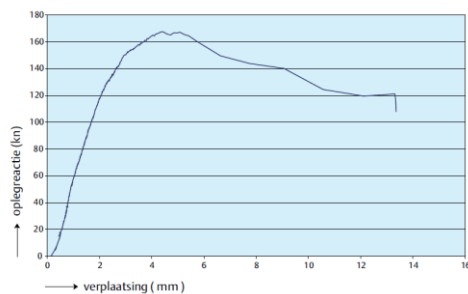
indirecte lastafdracht



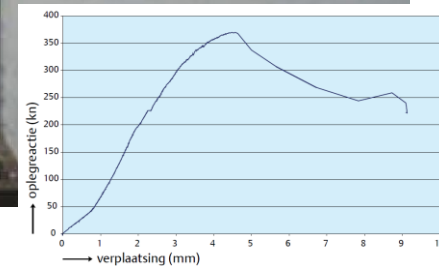
Experimenten



Experimenten



168 kN & 171 kN

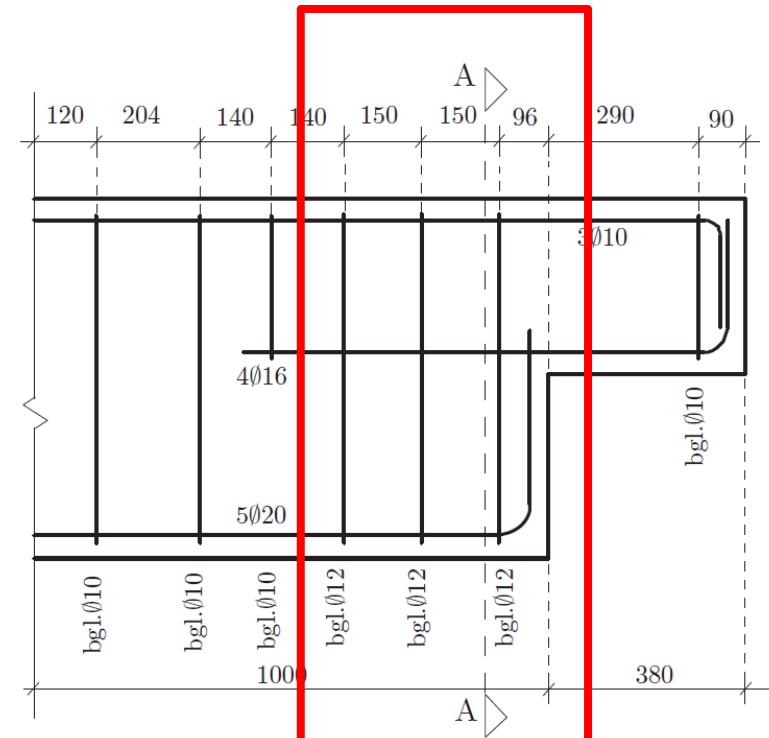
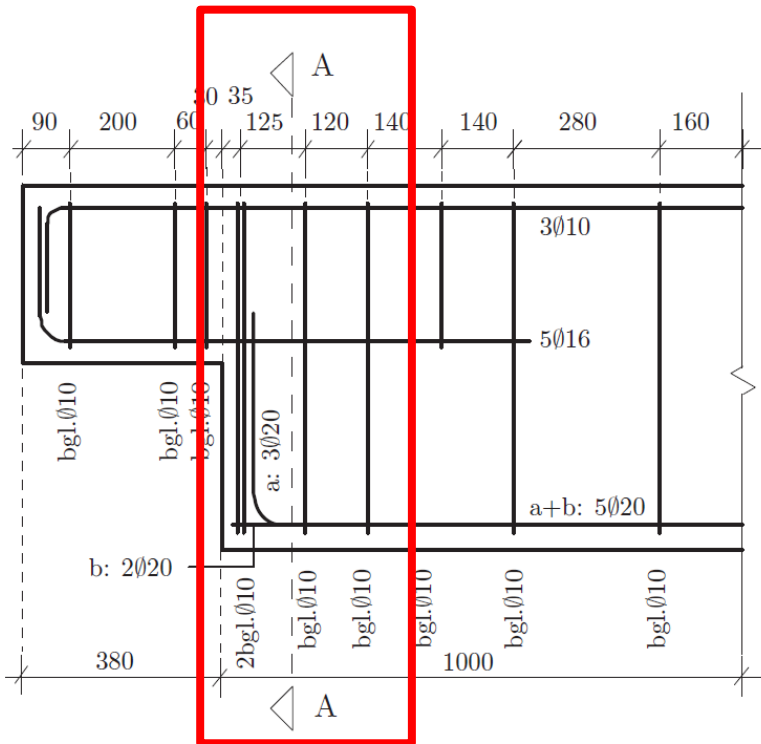


357 kN & 364 kN

oplegreacties bij bezwijken



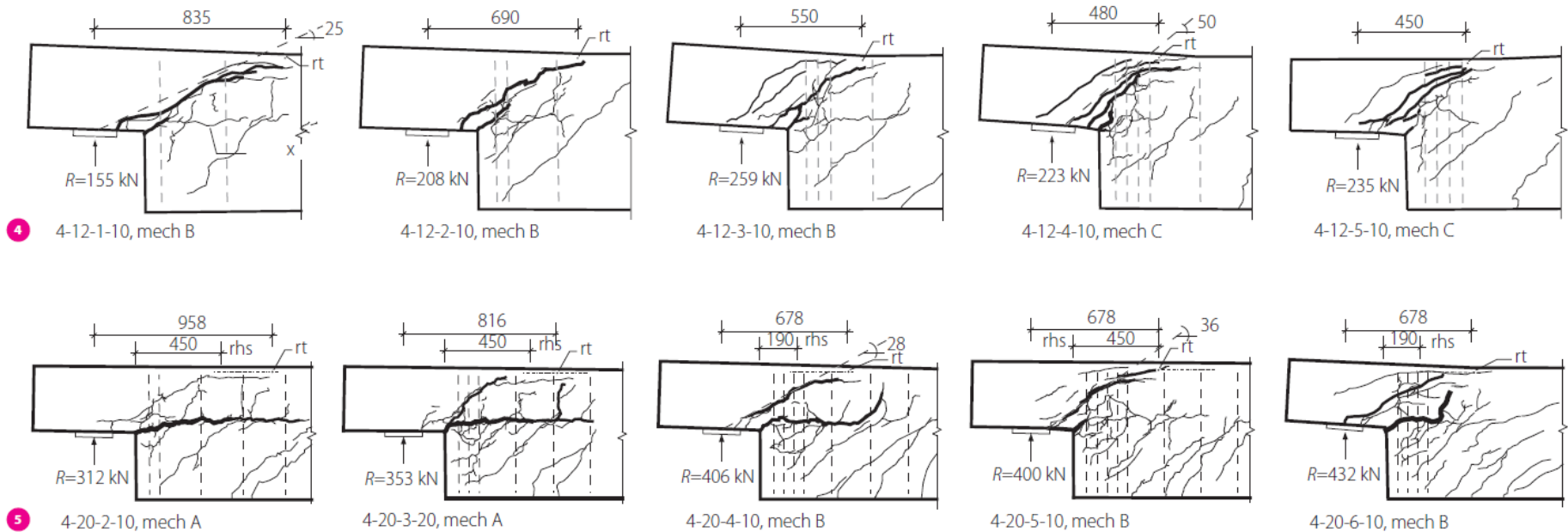
Experimenten TU/e (2)



invloed van de “verdeling” van de ophangwapening



Experimenten TU/e (2)



invloed van de buigtrekwapening onderin de tand en de ophangwapening (beugels) aan de kop van de balk

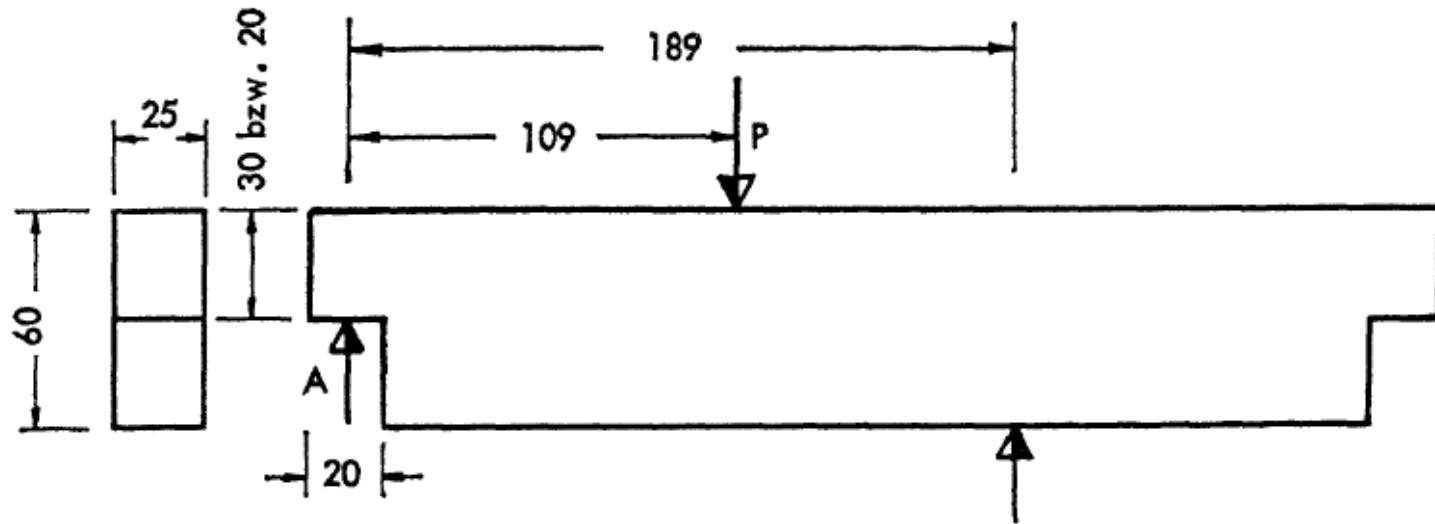
mechanismen:

A = dominerende horizontale scheur; rotatiepunt “veraf”

B = horizontale scheur i.c.m. schuine scheur in keel

C = dominerende schuine scheur in keel; rotatiepunt “dichtbij”

Experimenten Stuttgart

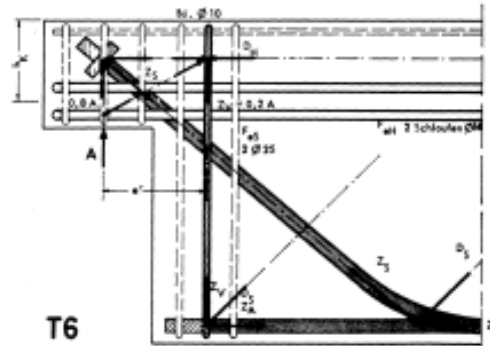
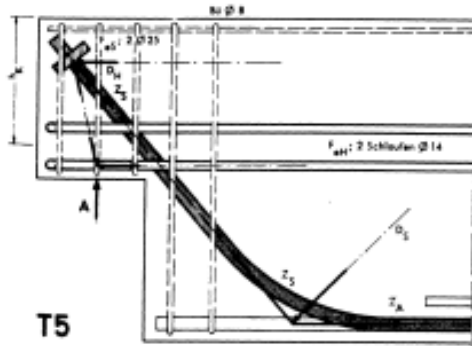
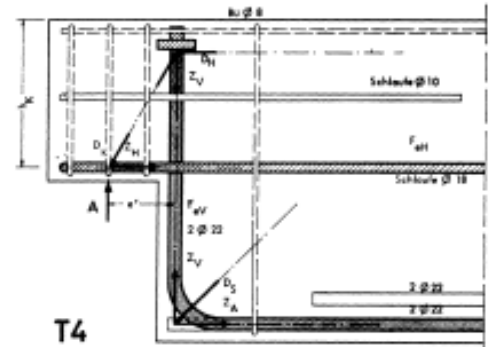
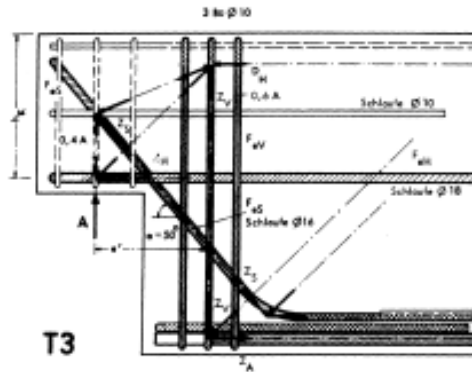
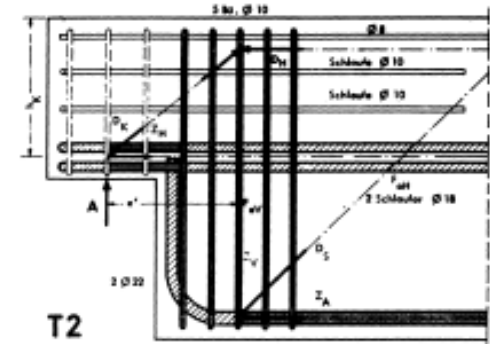
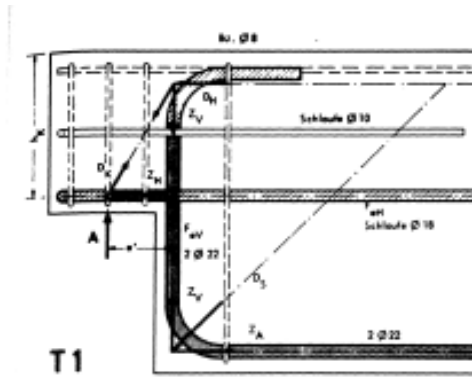


afmetingen in [cm]

Steinle/Rostásy, 1975

Experimenten

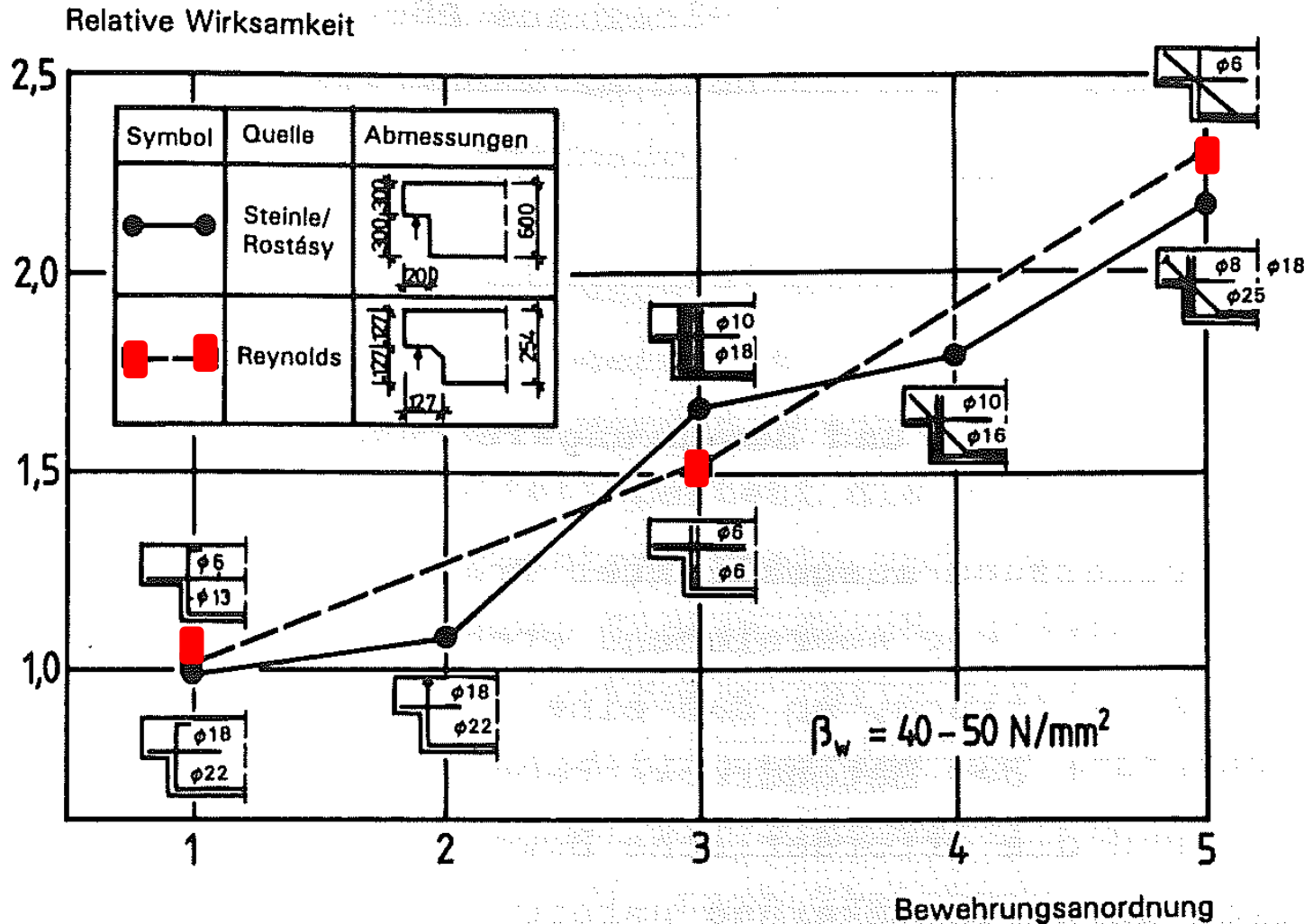
Voor T1 t/m T6:
Verticale ontbondene
van de ophangwapening:
760 tot 790 mm²



Experimenten

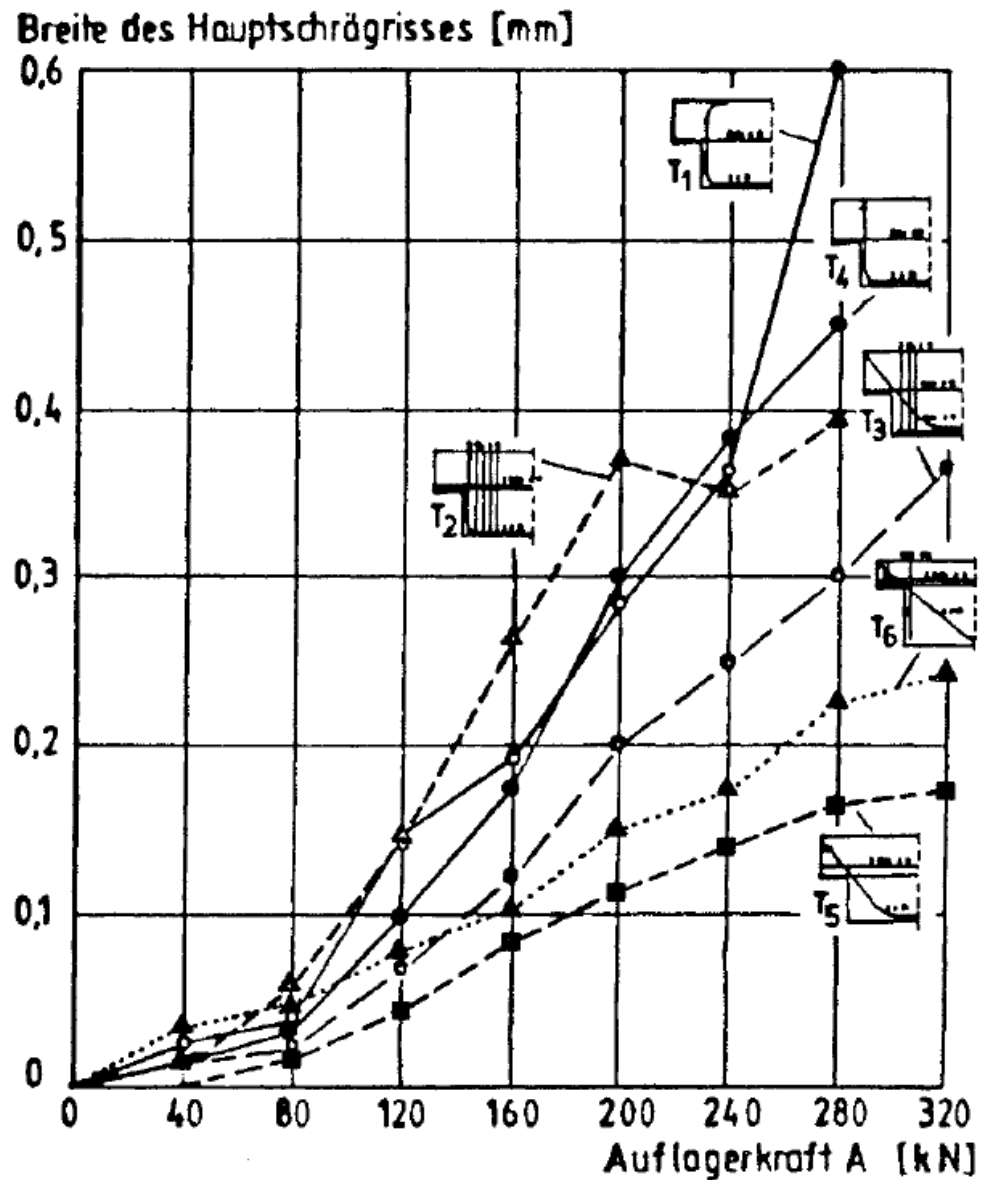
Relatieve effectiviteit:

De verhoudingen voor de gemeten bezwijklasten voor varianten met dezelfde hoeveelheid verticale wapening beschikbaar voor het opnemen van een ophangkracht

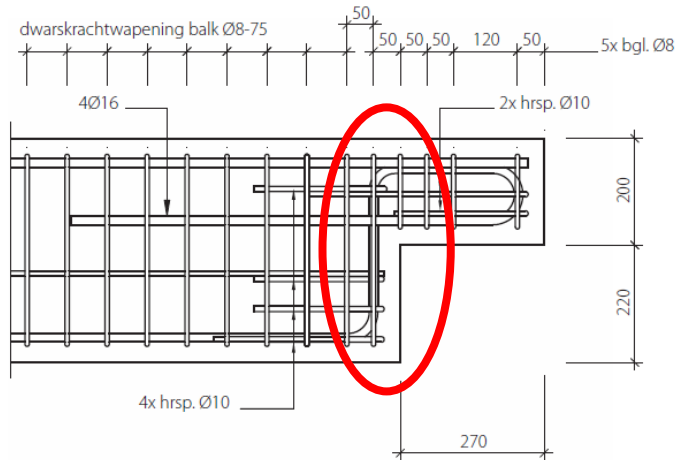


Experimenten

Gemiddelde
scheurwijdte in de keel
van de tand



Experimenten TU/e i.s.m. Lincon



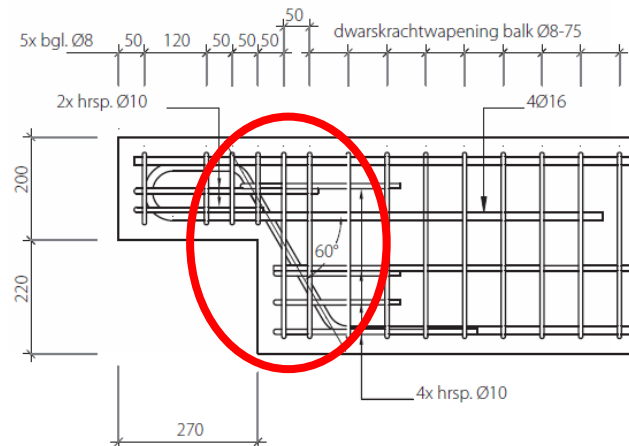
ophangwapening 4Ø16

verticaal (V1)

of

onder 60 graden (V2)

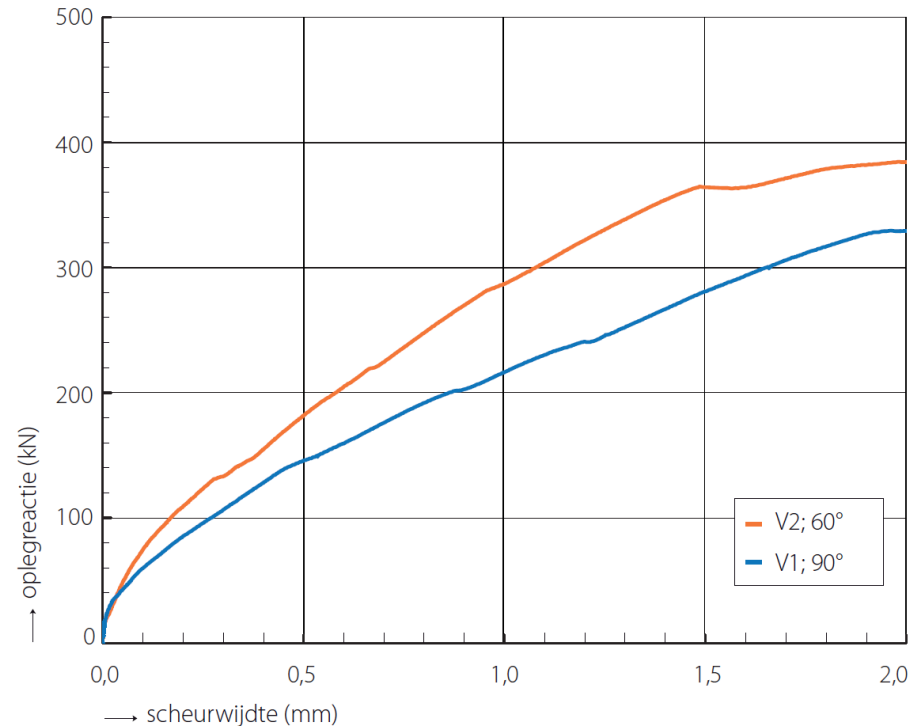
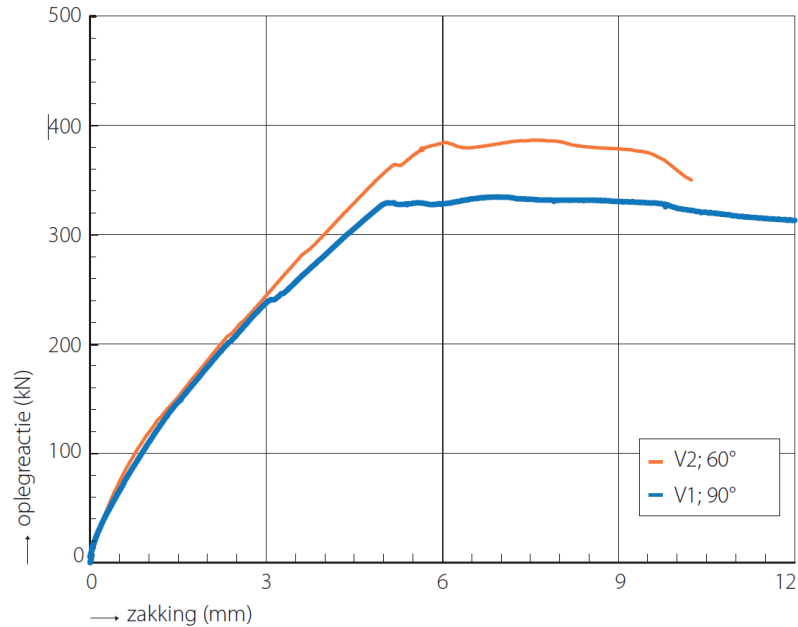
balkbreedte 350 mm



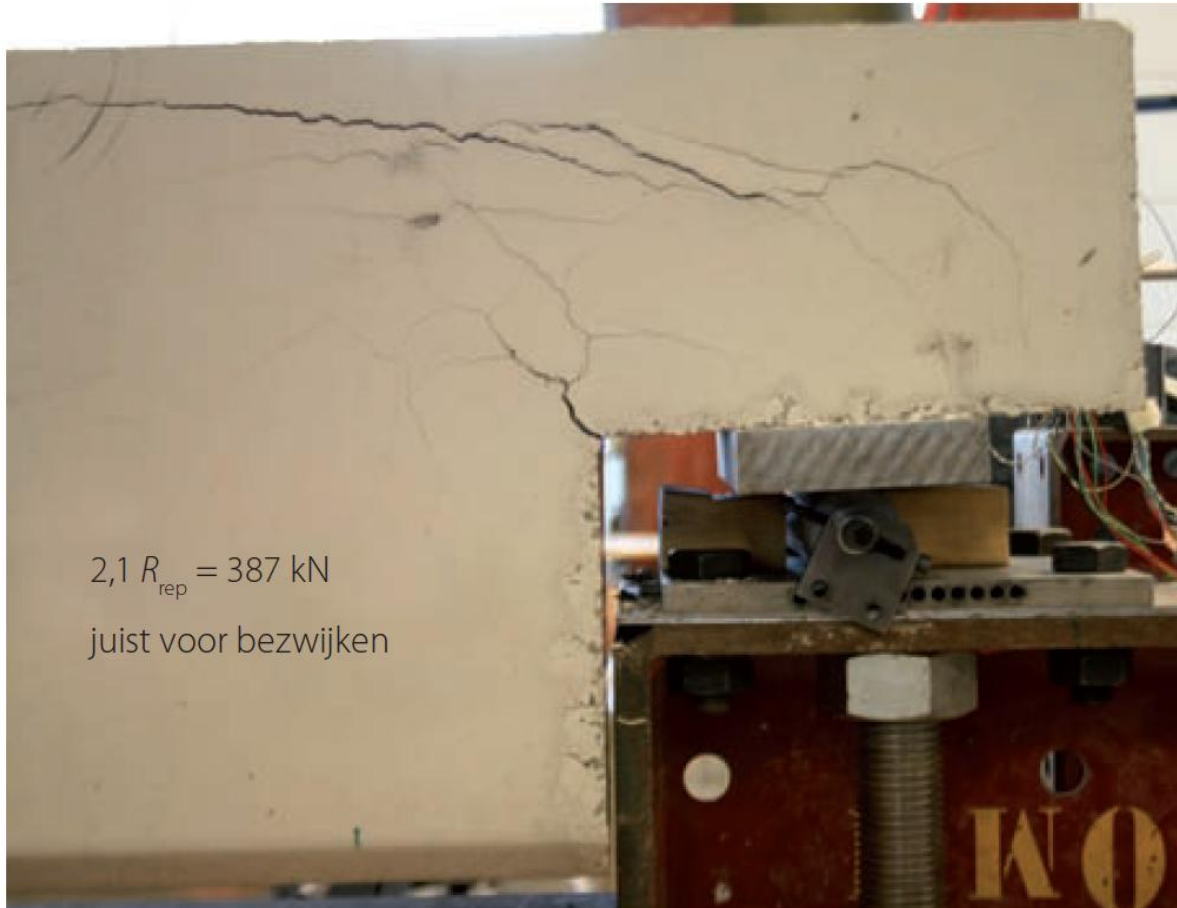
Experimenten

ophangwapening 4Ø16

verticaal (V1)
of
onder 60 graden (V2)



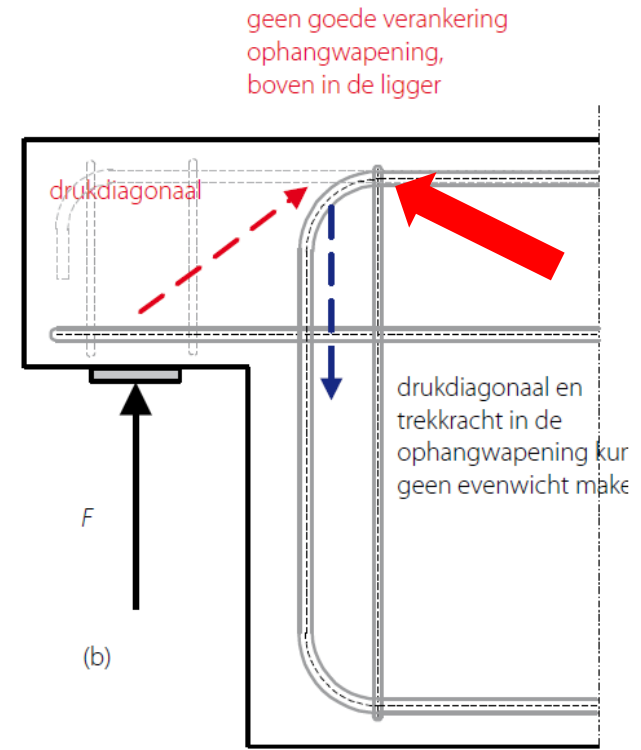
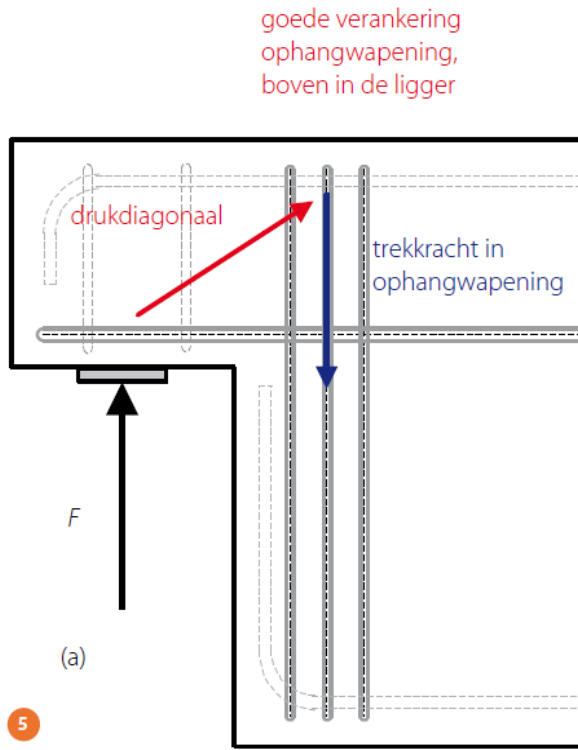
Experimenten



bezwijkbeeld

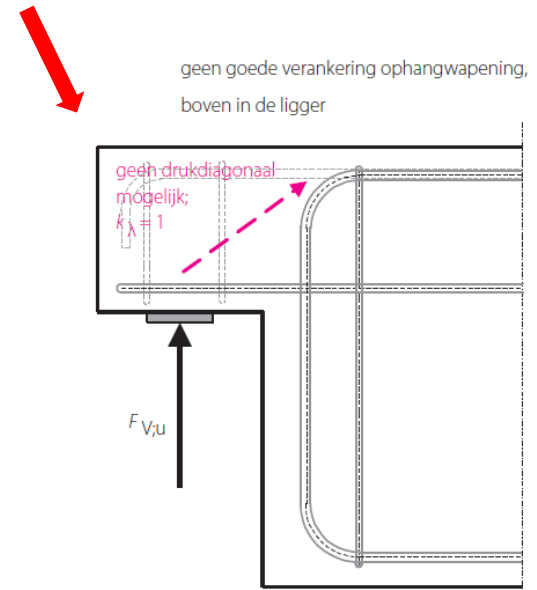
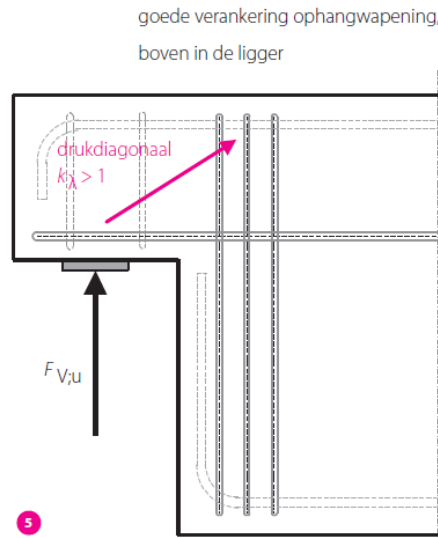
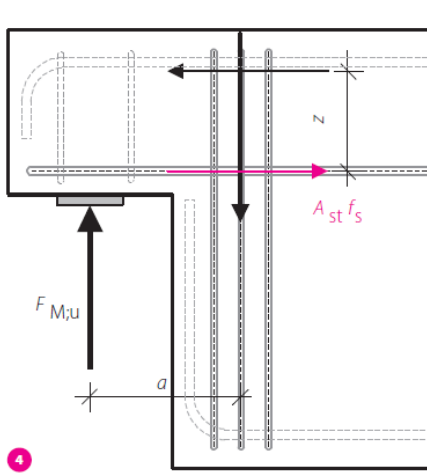
60 graden (V2)

Analyse proefresultaten



Wijte, Gijsbers, van der Veen, Kleinman; Cement 2010

Analyse proefresultaten



Gijsbers, van der Veen, Wijte; Cement 2009

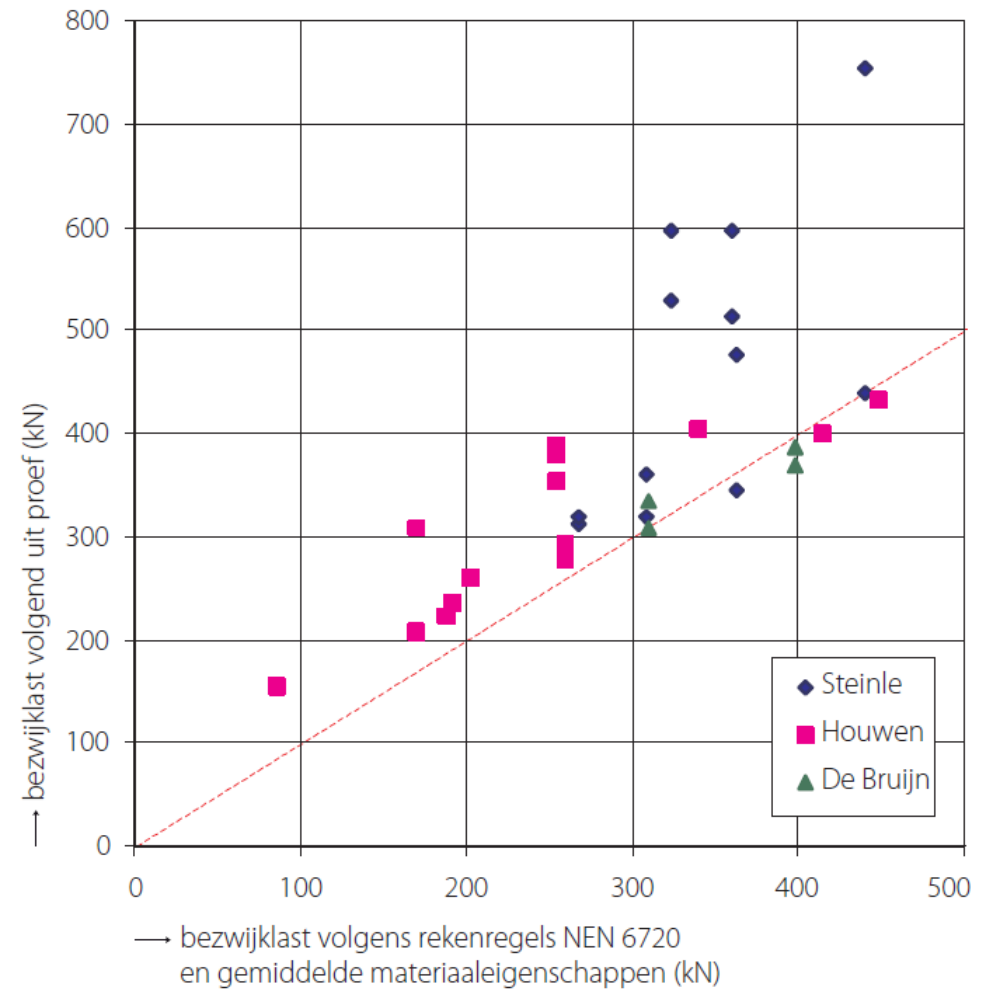
Analyse resultaten

Tabel 1 Proef- en berekeningsresultaten [kN] proefserie Steinle [7, 8]

proef	proefresultaten		berekeningsresultaten				verhouding proef/berekening	
	li	re	maatgevend	buiging	dwarskracht	ophangwapening	li	re
T1	312	320	268	307	268	398	1,16	1,19
T2	477	345	363	423	699	363	1,31	0,95
T3	514	496	360	371	744	360	1,42	1,38
T4	360	320	309	309	557	398	1,16	1,04
T5	>754	>440	440	656	896	440	>1,71	>1,00
T6	597	528	323	446	323	509	1,85	1,63

Tabel 2 Proef- en berekeningsresultaten [kN] proefserie Houwen [9]

proef	proefresultaat	berekeningsresultaten				verhouding proef/berekening
		maatgevend	buiging	dwarskracht	ophangwapening	
1-1	278	259	259	346	366	1,07
1-3	292	259	259	346	366	1,12
1-2	380	254	382	476	254	1,50
1-4	389	254	382	476	254	1,53
4-12-1-10	155	85	212	200	85	1,82
4-12-2-10	208	170	202	344	170	1,22
4-12-3-10	259	203	203	325	254	1,28
4-12-4-10	223	188	188	296	339	1,19
4-12-5-10	235	192	192	352	424	1,22
4-20-2-10	312	170	550	481	170	1,84
4-20-3-10	353	254	507	444	254	1,39
4-20-4-10	406	339	469	460	339	1,20
4-20-5-10	400	424	437	460	424	0,94
4-20-6-10	432	448	448	477	509	0,96



Aanbevelingen

verboden !

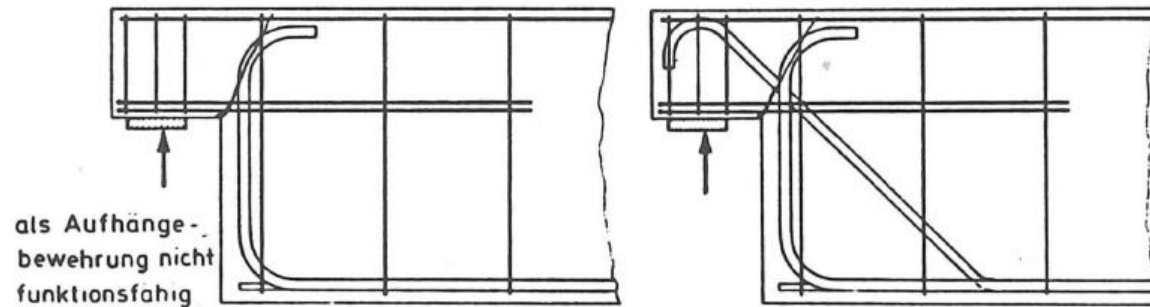


Bild 9.36 Aufgebogene dicke Gurtstäbe lassen sich in konsolartigen Auflagern nicht ohne Ankerplatten verankern

Die Druckstrebenkräfte des Balkens und der Konsole bedingen eine Aufhängebewehrung für die Zugkraft der Größe A . Damit die vom Auflager kommende **Druckstrebe gut abgefangen wird**, sollte die Aufhängebewehrung mindestens aus zwei Bügeln bestehen, die nahe der einspringenden Ecke innerhalb einer Länge von höchstens $0,5 d_k$ angeordnet werden. Sind die

Aanbevelingen

Snijpunt drukdiagonaal en ophangwapening moet een goede knoop vormen

Concentreer de beugels van de ophangwapening nabij de keel

Ophangkracht & scheurwijdtebeheersing:

- 1/3 door schuine ophangwapening

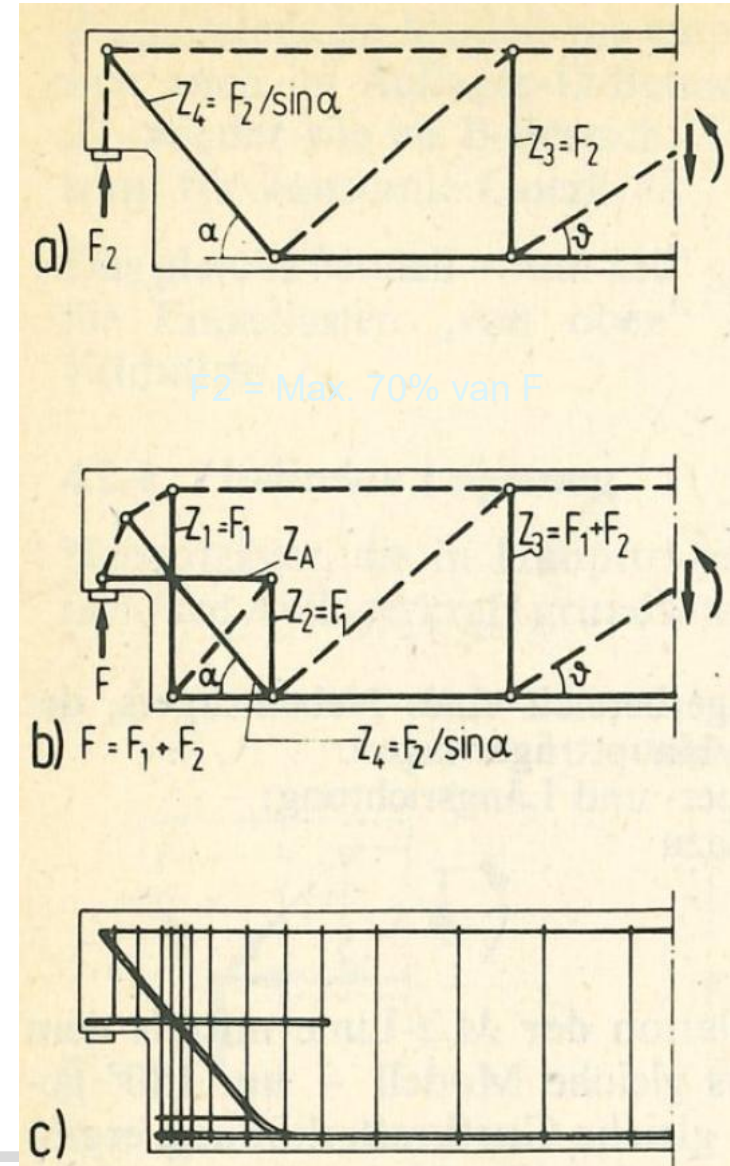
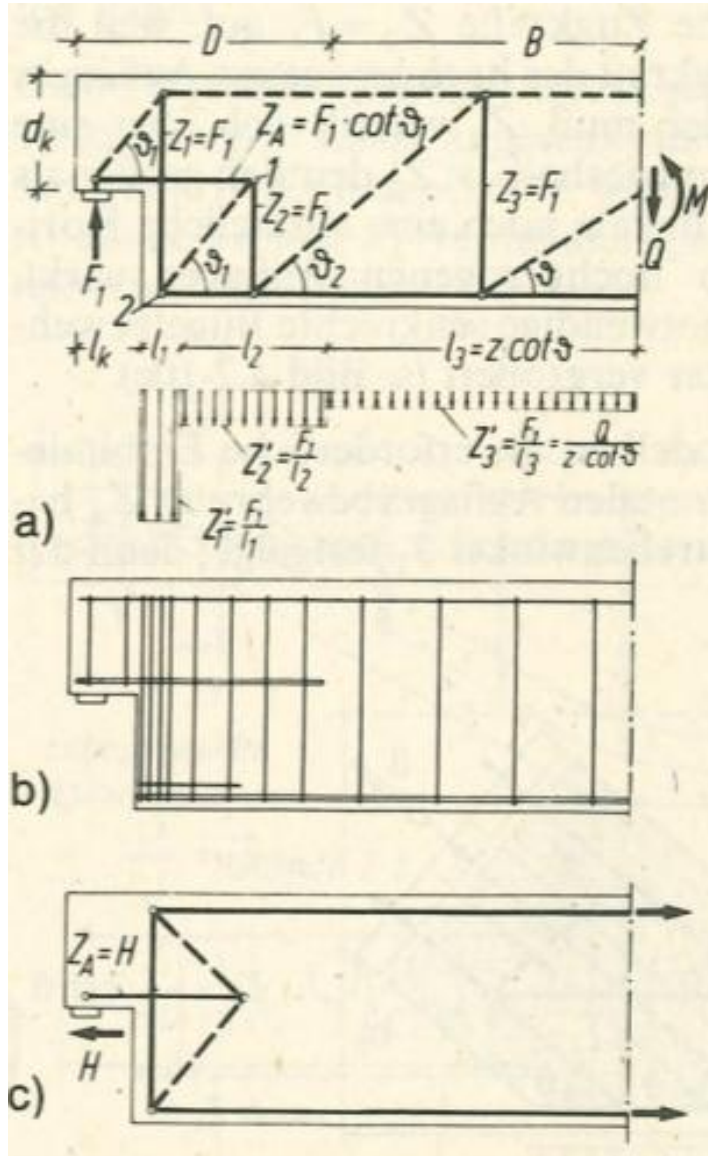
- 2/3 door verticale gesloten beugels

Alternatief:

- 100% verticale ophangwapening aangevuld met praktische schuine wapening



Aanbevelingen





EINDE





VRAGEN?

